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THE INNOVATION CHAIN IN RAIL TRANSPORT

Abstract
The paper proposes a classification of innovations in rail transport by compiling a catalog of innovations and introduces the notions of innovation diffusion and innovation chain. It also provides examples of innovative products and technology solutions developed by Polish manufacturers.

Key words
innovation, railways, innovation chain, innovation diffusion, rail industry, Poland.

Introduction

For more than a decade, the transport sector has been experiencing a proliferation of innovations. We have seen major developments in transport vehicles and transport infrastructure as well as in freight and passenger services. We can observe also innovations in funding methods and business models. Some of the innovations were previously unknown or impossible to implement, but now, supported by information systems, the Internet and mobile communications, they have become industry standards.

The paper seeks to propose a classification of innovations in rail transport. The discussion is illustrated with examples of innovative products that made a difference in Poland's rail transport sector: new or significantly enhanced products and services that led to major improvements in the quality and competitiveness of rail transport services.

Definitions and types of innovation

In the most general sense, the word "innovation" stands for introducing something new (in Latin: innovatio means "renewal", while novus means "new"). Diverse definitions of innovations can be found in numerous publications prepared by both Polish [1] [2] and foreign scholars [3] [4] [5]. Under the definition advocated by the OECD and the European Commission, innovation must be implementation-oriented: it is indeed "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations" [6, p. 46]. An innovation should therefore be perceived either as something that is newly implemented or as implementing something that is new to:

- the implementing organisation although it is already used by its competitors (e.g. selling tickets online),
- a given sector/industry, albeit employed in other sectors/industries (e.g. hybrid vehicles or usage-based billing for traction power),
- a geographic area, e.g. in a given country (although they are known and utilized in other countries, e.g. ERTMS (European Rail Traffic Management System)/ETCS (European Train Control System)).

Literature on the subject uses a variety of criteria to distinguish different types of innovation [1, pp. 92-95] [4] [7, pp. 11-27]. Common types relate to new materials, new products, new services, new processes, new organizational forms, as well as nee business models. The third edition of Oslo Manual [6] adopts a distinction into four basic categories of innovations: product innovations, process innovations, marketing innovations, and organizational innovations. Product innovations and process innovations are closely related to the concept of technological product and process innovation (TPP) used in the second edition of the Oslo Manual.

As Damanpour and Schneider [3, p. 216] emphasize "innovation is studied in many disciplines and has been defined from different perspectives". In the transport and logistics sector, a product innovation corresponds to the introduction of a good or service that is new or significantly improved in terms of its characteristics or intended uses, or whose performance is significantly better, to the effect that it provides the customer (user, passenger, forwarder/shipper, carrier, etc.) with clearly new benefits or added value. Therefore, this type of innovations is often called service product innovation. The terms "service product innovations" and "product innovations" have been used interchangeably in the literature to describe a particular set of innovations in service companies [8, p. 566]. The theory of innovation in services developed by Gallouj and Weinstein [9] has been widely discussed in service innovation literature [10, p. 139] [11]. Many researches also highlight that innovation does not just take place in products, but also in processes, and potentially, innovation can be combined from both process and product [11, p. 1361]. Several studies used a typology of service innovation that includes three modes: business model innovation, service product innovation, and service process innovation [4, p. 1362].

A process innovation denotes the deployment of a new or significantly improved production or delivery method (process) in various aspects of transport services, vehicle manufacturing, or transport management processes. It can involve significant changes in one or more of the elements of a process, such as: organization, technology, human resources, work methods, equipment, etc. Accordingly, an organizational innovation stands for the implementation of a new organizational method in a transport company's business practices, workplace organization or external relations.

Innovation is always linked to the notion of benefit or added value that a specific innovation brings, on the one hand, to suppliers – by enhancing their products or services portfolio and hence increasing their sales, operating margins or brand awareness – and on the other, to customers – by reducing the demand on their time or labor or by increasing the reliability of a product or service they use. In other words, innovations should benefit both the parties to transport-related (or, broadly speaking, logistics-related) transactions. A question arises, therefore, whether an innovation that makes no difference to either party makes any sense. Assuming that, conceivably, somebody did see good reasons to develop and implement the innovation, the question should perhaps be restated as follows: were all the uses of the innovation correctly identified and fully "exercised"? Was everything done to convince the organization and the customers that the innovation contributes added value, even if it is difficult to capture because it affects such things as public relations, user opinions, or following a trend or fashion?

Innovation chain in the transport sector

A distinctive characteristic of 21st century innovations in the transport sector is that they will concern all elements and stages of the transport process. In some cases, it is difficult to discriminate between product-, service- and process- related innovations, as they will overlap and intermingle: a product innovation project centered on a vehicle might at the same time entail a process innovation at the design or manufacturing stage. This is also true about some services. Baregheh *et. al.* defined innovation as "the multi-stage process whereby organizations transform ideas into new/improved products, service or processes, in order to advance, compete and differentiate themselves successfully in their marketplace" [4].

It could be therefore theorized that no innovation should be viewed outside its context and without taking account of its place in the value chain and the supply chain. A change (innovation) introduced at one point implies or enables changes to other links (elements) in the chain: streamlining a process, launching a new service, creating a new customer service process, or developing an entirely new business model, to name just a few such changes. Recognizing how important it is for innovation to propagate throughout supply chains, Laskowska-Rutkowska has put forth the concept of "diffusion of innovations in a supply chain" [1].

Innovations to design and manufacture processes yield new or modified products, characterized by new features, properties or capabilities in terms of, for example, durability, consumption of materials, pollutant emissions, reliability or safety. Product innovations like these (involving components or final products, such as vehicles or transport infrastructure systems) will soon inevitably result in the provision of new or modified services (internal as well as external), and hence will lead to transforming or developing the underlying service delivery processes in which the new or modified products have been deployed. The emergent service innovation might, in turn, trigger changes in the subsequent service use process. A chain of innovation can be longer or shorter, it may be, for example, truncated to a service alone or to a service and some related processes, but in most cases seemingly isolated innovations can be in fact traced back to a prior global and universal innovation, such as e.g. mobile telecommunications or the Internet.

Given these facts, it is possible to define a chain of innovation in transport as an alternating sequence of product, service and process developments such that applying an innovation to a single element allows modifications to other elements aiming to derive (economic, social, environmental, etc.) benefits from their use.

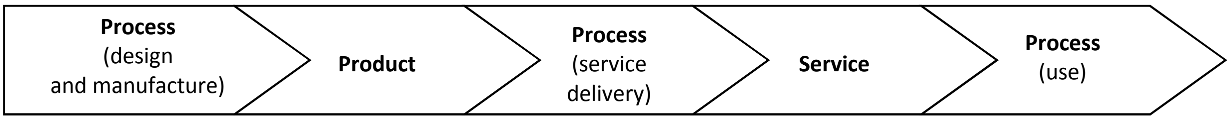

Fig. 1. A chain of innovation in the transport sector
Source: Authors'.

An innovation chain is exemplified e.g. by the process of rapid design, visualization and simulation of vehicle chassis and interior, enabling engineers to build multiple variants of a vehicle and demonstrate them to the customer at an early stage of development. Some of these variants may be approved for production or offered as an after-sales option (i.e. after the vehicle, a passenger car in this case, comes into use). As an effect, buyers – vehicle fleet owners (e.g. a so called RoSCo – Rolling Stock Company) – can enhance their service delivery processes by offering operators (e.g. passenger transport operators) the rental of, besides basic non-modifiable vehicles, customizable vehicles whose interiors can be reconfigured by users to suit their specific needs, either one-time prior to use or multiple times (e.g. on weekdays or on weekends – a weekday vs. a weekend setup), depending on the flexibility of a particular design.

To demonstrate the complexity of the innovation chain in rail transport this paper attempts to arrange innovations into three groups – product (technology) innovations, service innovations, and process innovations – and to categorize them at different levels.

Product innovations in rail transport

Product innovations can involve rail vehicles, transport infrastructure, or both. They will include, primarily:

1. Interoperable multi-system rail vehicles that can operate with diverse types of traction power networks and systems.
2. Signalling systems of ERTMS/ETCS or PTC (Positive Train Control) class providing for interoperability on main lines or allowing continued use of low-traffic lines as a result of substantial cost savings on infrastructure maintenance.
3. The development of base models of products (e.g. vehicles) with multiple variants that are customizable to user preferences (specifications), and the construction of user-configurable vehicles (mostly for passenger transport) that can be easily adapted to users' temporary requirements, e.g. to meet demand for extra business class seats or to cater to special-needs groups (persons with small children, tourists, cyclists, people with reduced mobility).
4. Various types of flat platform wagons for intermodal (containerized) transport.
5. The application of composite materials and nanomaterials to reduce vehicle weight, thus bringing down energy consumption, and to optimize surface finishes (dirt-resistant outer shell coating/sheathing, window glass as well as seat upholstery and other elements of interior decoration characterized by very high dirt or liquid resistance).
6. Electric cars with solutions addressing the last mile problem, enabling them to cover short distances using stored energy or auxiliary diesel engines (as when moving in industrial spurs and other secondary tracks, entering a repair facility, or providing mobility in case of traction power loss) and hence reducing the need for replacement or shunting vehicles.
7. Diesel engines with lower and lower greenhouse gas emissions.
8. Electric engines of increased efficiency.
9. Hybrid cars powered by diesel and electric engines.
10. Hydrogen cell technologies.
11. Inductive (wireless non-contact) electric vehicle charging systems for large road and rail vehicles (trams, buses, trucks, etc.).
12. Kinetic and thermal energy recuperation mechanisms and systems.
13. Mechanical energy storage devices (modern "flywheels").
14. Section switching of traction current – pedestrian-safe third rail systems for trams and trolleybuses.
15. Photovoltaic power and wind power for selected infrastructure components.
16. Noise reduction systems – internal and external, active or passive.

17. Closed circuit systems for water, liquid waste and operating fluids to prevent leakage.
18. Crash zones and safety cells in rail vehicles.
19. Radio systems for remote control of locomotives operating in closed areas or using of switch engines in industrial yards.
20. Radio and telecommunication systems, including voice and data transmission systems, such as GSM-R.
21. Internet access (WiFi) inside vehicles and passenger service facilities (e.g. on stations).
22. Traction control and anti-slip systems.
23. Anti-collision warning systems, with an autonomous emergency braking feature, installed in road and rail vehicles.
24. Integration or unification of communication and data exchange standards among onboard control systems.
25. Diagnostics systems including:
    - automatic reading and interpretation of diagnostic information and alerts,
    - data recorders and black boxes,
    - rolling stock condition monitoring devices (eg. DSAT),
    - infrastructure surveillance systems to prevent unauthorized access,
    - predictive diagnostics.
26. Wild animal deterring devices installable along railroads.
27. Hybrid solutions addressing pedestrian crossing safety on roads and railways (illuminated traffic sign frames, crossings with lights-on switching on detecting an oncoming vehicle, or warning systems dedicated to non-guarded road-rail crossings).
28. Transport planning and management support systems based on state-of-the-art information technology, involving the use of algorithms and databases to help optimize the planning and monitoring of shipments as well as the deployment of personnel and rolling stock, or scheduling routes and timetables.
29. CCTV surveillance, panic/anti-theft alarms, intercom systems for communication between passengers and cabin crew (including the driver).
30. Passenger information display and voice announcement systems (for use both in vehicles and facilities) as well as infotainment solutions combining information with entertainment or advertising functions (interspersed with information content).
31. Improvements in travel ergonomics and comfort, including new appliances and solutions to facilitate the delivery of transport services to elderly and disabled persons (e.g. with mobility handicaps or sight and hearing impairments), such as stair lifts and platform lifts, drive-up ramps, pull-out steps and ramps, door buttons (including Braille buttons) activating car doors, pagers (beepers), voice and video announcements, voice/sign language translation kiosks, seats for wheelchair users (equipped with belts or other fasteners), wheelchair accessible toilets and passages, seats for mothers with infants.
32. Training simulators, including 3D visualisation systems.
33. New transport vehicles, e.g. aircraft- or helicopter-type drones used for rail cargo tracking as well as railway infrastructure monitoring.

Service innovations in rail transport

While it is true that most service innovations are associated with innovative products whose availability has driven efforts to introduce new services, wherever it is the service that plays a more significant role, such innovations are deemed to belong in this category:

1. Short- or long-term rental of transport vehicles where the service includes hire of personnel and maintenance.
2. Internet-based customer experience, automation of sales and information desk functions, mobile solutions (tickets, timetables, info- and helpline, parcel tracking).
3. Cargo tracking and micro cargo delivery (courier services, containerized cargo as well as bulk cargo).
4. Mapping of traffic flows and passenger behaviour (transport planning) through e.g. the use of vehicle count systems (roads), passenger count systems (public transport), and trip (origin-destination) matrices.

This category can also comprise two product-process-service aggregates in which the service factor is prevalent. These include:

5. Intermodal transport, which is not in itself an absolute novelty, as it dates back to around the middle of the 20th century. Increasingly supported by modern information technologies and hence easier to handle (single large shipments have become convenient to describe, identify, move, track and transfer

between modes of transport), intermodal transport has been growing ever since. Nowadays one may indicate also growth of unified passenger intermodal transport (rail-bus-tram-(air) at least).

6. Low-cost railways, a concept/model that was originated and first implemented in air transport in the US (South-West Airways), has been growing dynamically in Europe since the late 1990s, chiefly as a result of deregulation in most European markets, previously monopolized by government-run companies. The "low-cost carrier" service (internally: process) is based on a blend of two ideas. First, it is a minimum services portfolio built around a single service that must be kept as cheap as possible while some add-on and à la carte features, such as meals, extra luggage, or call centre services, are offered at a much higher margin. Second, it is a unique ticket pricing policy: when booked early, tickets are sold at very low, almost negligible prices. It appears that this combination ensures an immediate market success.

Process innovations in rail transport

Process innovations can relate to design and manufacture, service delivery, or use of services. The first group includes, for example:

1. Building vehicles or e.g. control and communication systems from standard manufactured elements, preferably from easily available COTS (commercial off-the-shelf) components, that could be used across all product families.
2. Rapid design supported with 3D modelling and prototyping as well as with endurance testing and MES analysis.

The second group, encompassing processes that support service delivery, includes e.g. the following:

3. Construction and maintenance processes, including:
   - public contracts of the "design-and-build" or "design-build-and-maintain" type,
   - outsourcing of fleet and infrastructure management (may be limited to certain subsystems) – annual and multiannual contracts.
4. Funding models (schemes):
   - for transport infrastructure, e.g. public-private partnership (PPP), project finance models, licensing and permits, etc.,
   - for vehicles and fleets of vehicles, such as leasing, rental, and group purchasing organizations (GPOs, sometimes in *ad hoc* form) allowing buyers to achieve economies of scale and leverage their purchasing power.

The last group of innovations, viz. those pertaining to use processes, comprises e.g. the following:

5. Use of techniques based on energy-efficient dynamics for the acceleration and braking of trains.
6. Maintenance processes based on accurate and up-to-date information on a vehicle's or device's condition rather than on average inspection intervals.

Examples of innovations in the Polish rail market

Railway industry has a long-standing tradition in the area of today's Poland (this includes territories that were formerly controlled by other states). At the moment, the railway industry is made up of over 200 significant actors, among which there are both global and local players. Transport services are provided by more than 80 licensed railway undertakings. Illustrative examples of innovations that have already been deployed in Poland's rail transport market are provided in Tables 1-3.

Table 1. Examples of product innovations in Poland's rail sector

Innovation	**Domestic examples**
Multi-system vehicles	Newag, Pesa
Multi-variant and customizable vehicles	Pesa, Newag, Solaris
Track superstructure components	Track Tec, KZN Bieżanów
Application of crash technology to the construction of car bumpers	Axtone
Wild animal deterrent devices	Neel
State-of-the-art materials, crash zones, safety cells, closed circulation of water, liquid waste and operating fluids	Alstom PL, Solaris, Newag, Pesa, Modertrans, FPS Cegielski
Modern engines and energy sources, last	Bombardier & Solaris, VISSystem, Pesa (*Marathon*), Newag

mile solutions, power-packs	
Interoperational ERTMS/ETCS systems	Bombardier PL, Thales PL
Remote control of switch engines	ArcelorMittal PL (user)
Communication	APM, Radionika, Pyrylandia, Kapsch PL
Internet access (WiFi) in transport vehicles	T-Mobile in partnership with PKP Intercity, Koleje Mazowieckie, some of the rail vehicles operated by Koleje Śląskie and Koleje Dolnośląskie
Diagnostics	Bombardier PL, VAE TENS, EC, ATM
Road and rail safety	KZA Kraków (Dysonapp system), Bombardier PL, Kombud, KZA Lublin, Sygnały Rybnik, APM
Transport planning and optimization systems	PKP PLK SA, PKP Informatyka, Basement Systems, Nodus, DPK, and many more in the IT industry
Simulators	I3D
Passenger information display and voice announcement systems; infotainment	KZŁ, R&G, TK Telekom

Source: Author's.

Table 2. Examples of service innovations in Poland's rail sector

Innovation	**Domestic examples**
Internet-based customer services, sales process and help desk automation, mobile solutions, passenger train tracking, mobile ticket booking platforms	PKP PLK, PKP Informatyka, TK Telekom and its subcontractors, Astarium Koleo, blik, moBilet, SkyCash, jakDojade.pl, e-podróżnik.pl, and many more
Tracking of locomotives, wagons, cargo shipments	Wasko, Elte, and many other
Combined services including manufacture, delivery and assembly of railroad switches	Track Tec, KZN Bieżanów
Low-cost rail connections	PKP Intercity (*TLK* trains)
Premium service	PKP Intercity (*Pendolino* trains)

Source: Author's.

Table 3. Examples of process innovations in Poland's rail sector

Area	**Distinctive characteristics**	**Domestic example**
Design	Unification/standardization, reliance on COTS components, FEM modeling and analysis, 3D design	Newag, Pesa, Solaris, EC Engineering, Inteco and other
Infrastructure and fleet financing schemes	Financing models for transport infrastructure (public-private partnerships, project finance models)	Pomorska Kolej Metropolitalna
	Funding models for cars and fleets (leasing, group purchasing organizations allowing buyers to achieve economies of scale, rental)	Południowa Grupa Zakupowa (covering 4 regions)
Construction and maintenance processes	Development and maintenance process: - types of public contracts, e.g. *design-build* or *design-build-maintain* - maintenance process outsourcing in regard of infrastructure or its subsystems (annual and multiannual contracts)	PKP PLK

Source: Author's.

Examples of product innovations by Polish companies

PESA BYDGOSZCZ
The reputation of Polish innovative technology has been built, to a large extent, by PESA – the Bydgoszcz-based rolling stock manufacturer and the first company from Central-Eastern Europe to have won, in March 2014, the prestigious Boldness in Business award by *The Financial Times* and ArcelorMittal. In 2015, PESA emerged as one of the world's leading tram manufacturers.

The milestones in the company's innovation success story include:

- 1994 – the first foreign contract to make sleeping cars for Lithuania.
- 1995 – ZNTK Bydgoszcz (company's former name) obtains a patent for a non-sparking brake shoes for rolling stock.
- 2001 – the company starts making the railbus called *Partner*. A further series of vehicles based on the *Partner* soon to follow.
- 2004 – the first wide-gauge diesel engine powered railbus made for Ukrainian railways. Launch of the EN95 class electric multiple unit (EMU) for the Warsaw Commuter Rail (Warszawska Kolej Dojazdowa – WKD), the Polish capital's suburban transit system.
- 2005 – entry into the tram market. Its latest tram model named *Twist* can recuperate energy while decelerating and return it to the network (or, optionally, store it in energy containers). Under emergency conditions, it is possible to use the stored energy to move the tram. Since the trams support online diagnostics, fleet managers can remotely monitor them.
- since 2006 – the company supplies diesel- and electric powered rail vehicles (including the *ELF* family) to all regions of Poland as well as to Ukraine, Lithuania, and Italy.
- 2012 – an electric locomotive developed as part of the *Gama* modular locomotive family, which includes locomotives powered by a 2400 kW diesel engine and capable of a maximum speed of 160 km/h alongside an electric locomotive line comprising single-system (with the optional *Marathon* auxiliary diesel engine allowing it to cover a minimum distance of 42 kilometres) and multi-system locomotives powered at 1.5kV DC, 3kV DC, 15kV AC or 25kV AC and doing up to 140 km/h in freight transport or 200 km/h in passenger transport. A key characteristic of the Gama locomotive family is the use of standardized modules that can be mounted on different types of locomotives, making the cars a lot easier to service.
- 2015 – first *Dart* trains delivered – a new generation of intercity class EMU trains geared to meet the requirements of European and global operators for long-distance lines. *Dart* units can be powered by a range of voltages and run at operating speeds of up to 250 km/h.

NEWAG
In its early years in business, the company specialized in maintenance and upgrading locomotives for passenger and freight rail operators present in Poland's market. Here is a brief record of the company's innovation achievements:

- 2005 – the premiere of a new EMU of the 14WE series; upgrades to diesel powered locomotives: 6D, 16D, 311D.
- 2009 – the new build 19WE EMU launched as well as the *Dragon* electric locomotive, the only wholly Polish-built car in 25-years' time, designed to haul heavy cargo trains.
- 2010 – the introduction of the first diesel multiple units (DMU) SA137 and SA138.
- 2011 – a contract signed between the Siemens-Newag consortium and Metro Warszawskie [Warsaw Metro] for the delivery of 35 six-car *Inspiro* trains.
- 2012:
  - the new *Nevelo* 126N tram developed;
  - the electric six-unit train 35WE – first in the *Impuls* family. *Impuls* multiple units can be shipped in a number of configurations (from two to six cars per unit). Besides variable length, multiple variants of passenger car interior are available, which makes the trains suitable for urban and suburban use as well as for long-distance routes. In 2013, a multiple unit from the *Impuls* family exceeded 211 km/h, setting Poland's speed record;
  - launch of the E4MSU *Griffin* from a family of 4-axle electric engines, the first Polish multi-system locomotive.

At the international ERCI Innovation Awards event held in November 2015, Newag was named Europe's most innovative rail company, over such competitors as Alstom and Ansaldo Breda. The award-winning project

"Europe's first Polish-built TSI-compliant 6-axle multi-system electric locomotive for heavy freight trains" was co-funded by the National Centre for Research and Development (NCBR). An international jury assessed runner-up projects on three aspects: innovative merit, effect on strengthening the company's competitive advantage, and networking with other enterprises and research institutions.

TRACK TEC

Track Tec Group is a leading supplier of track superstructure materials and elements. The Group is composed of seven manufacturing plants or facilities, three of them making railroad turnouts and fastenings, and the other four producing railroad ties and sleepers. The Group's principal product lines are pre-stressed concrete and wooden track sleepers, railroad and tram turnouts, rails, as well as level crossing plates, platform elements, and water and cable ducts. Track Tec designates itself as a one-stop shop for track construction, providing a comprehensive range of products and services including: engineering and design, manufacturing, transport and logistics, assembly and installation, alongside technical assistance, servicing, and maintenance inspections.
Its most recent innovation is a crossover switch supported on pre-stressed concrete sleepers and characterized by the application of entirely new solutions to the design of its components. The crossovers will be mounted on dedicated pre-stressed concrete sleepers instead of on traditionally used wooden ones. This will not only extend their life but also enhance their performance characteristics, e.g. increasing the travel speed to 120 km/h. In 2015, the product was awarded the "Rail Market's Engine" prize in the "Innovation" category.

Another highlight among the company's services is the highly innovative Track Tec turnout construction train, capable of transporting turnout parts on pre-stressed concrete sleepers. Before that, segments of that size were not carried by rail in Poland, as it involved the use of specialized vehicles that were not available domestically. The method developed by Track Tec uses three wagons to ship a fully assembled, ready-to-install turnout to any given location within the railway network. Its novelty lies in the use of the technical device UR-1, which was built in collaboration with EC Engineering and, when installed on a wagon, makes it possible to safely transport factory-assembled turnout parts on pre-stressed concrete sleepers to the construction site and to install them directly from the wagon onto the track bed.

The next step was to complement their service offering by providing a complete logistics service. To go with their wagons, the company purchased several electric and diesel powered locomotives, a railroad crane with a lifting capacity of 45-tons, capable of load-lifting under overhead lines, as well as some self-unloading wagons. The method described above reduces the time to complete trackwork, thus minimizing track closures resulting in inconveniences for operators and their customers. Owing to a progressive logistics solution, the order processing time has shrunk from six weeks to just a couple of days. The turnout construction train (*PZR*) won the first award in the "Rolling Stock" category in the Ernest Malinowski Contest held as part of the 2015 TRAKO fair in Gdańsk, Poland. The first customer order was filled by the *PZR* train in December 2015, by transporting two R300 turnouts from manufacturing site to assembly location distant ca. 100 km. It took around two and a half hours to lay a single block. The state-owned infrastructure manager PKP PLK intends to start using the method widely in assembling, transporting and installing turnouts on Polish railways.

NEEL

This Warsaw-based company was established in 1993 by former employees of the Railway Science and Technology Center (renamed the Railway Institute in 2010). The name is said to have been derived from the phrase "New Electronics for New Ecology". NEEL delivers systems protecting people's as well as animals' safety that reflect a commitment to promoting peaceful coexistence of humans and nature. Following a decade of research and development effort, the company built and launched a device representing a globally unique innovation – the UOZ-1 animal protection (deterring) device for installation along railway tracks. For several years now, the device has been operational in Poland and Russia, and is reported to deliver top performance.

The design of the revolutionary UOZ-1 animal protection device draws on a thorough understanding of rail traffic, animal behaviour and on the use of authentic animal sounds. It is activated by an approaching train and disabled as soon as the train moves away far enough. Its operation is founded on what we know about animals and their behaviour, and appeals to their survival instinct. Therefore, natural acoustic signals are utilized to deter them – a universal code understood by nearly all species of large animals. The UOZ-1 devices can be installed at intersections of railways and animal migration routes, minimizing losses in animal populations attributable to collisions with high-speed trains. Admittedly, accidents involving big animals, such as elk, deer, or a pack of wild boar, may be also hazardous for trains and passengers.

As a matter of fact, animal collisions have become an issue for many rail operators. In 2014 PKP Intercity, a major Polish passenger rail operator, spent nearly 470,000 Polish zloty only to repair its locomotives that were damaged in animal-related incidents (i.e. the amount does not include infrastructure repairs). In the first quarter of 2015, costs incurred by the operator in repairing the ED250 (*Pendolino*) trains approximated 200,000 Polish zloty.

AXTONE

AXTONE Group pioneers innovative crash energy absorption solutions targeted at all types of rail vehicles. The company has developed and patented the advanced Crash technology based on permanent plastic deformation of a piece of metal that is sheared out of the outer surface of buffer body. The technology was first employed in buffer manufacture in 2005. It helps mitigate the impact of low-speed collisions by intercepting and absorbing much of the arising energy. It thus addresses passive safety in rail transport, helping protect people, goods and vehicles. The original Polish elastomer technologies and Crash solutions have already gained visibility with customers throughout the world.

Conclusions

The idea of smart, integrated and green transport has been inscribed in EU transport policy and is pursued through such priority initiatives as In2Rail, IT2Rail or Shift2Rail. Innovative rail transport plays an important role in the overarching innovation process and is currently focused on intermodality of both freight transport and public passenger transport. Some of the new technologies introduced in the rail sector are adapted from, or based on, solutions previously implemented in other industry sectors.

Innovative products, services and processes designed and implemented by leading Polish manufacturers have established a presence in a number of markets. The modular locomotive families developed by PESA and NEWAG enable these companies to offer multi-variant products that can satisfy the needs of operators in different segments of the rail market. Track Tec's cutting edge solutions combine product, service and process innovations to epitomize the conceptions of innovation chain and innovation diffusion in the transport sector. The globally unique UOZ-1 devices supplied by NEEL represent a ground-breaking Polish technology that increases safety in rail traffic while at the same time embodying true concern for natural environment. Axtone is a global leader in crashworthy systems that are relevant to passive safety in rail transport, protecting people, goods and vehicles traveling on rail. Bombardier Transportation ZWUS (signalling systems), Medcom (electrical subsystems) and EC Engineering (design) are further examples of Polish companies that have become vital elements of the rail industry's chain of innovation.

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