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Innovative processes in passenger transport in Poland and Europe

Procesy innowacyjne w transporcie pasażerskim w Polsce i Europie

Abstract. The subject of research were innovative processes of a technological, organizational, structural, market or sociological nature. The starting material for developing the studied subject was the analysis of the dynamics of changes in expenditure on research and development in the field of transport infrastructure in Poland and the European Union. It has been found that in the last two decades, innovations in passenger transport have been successively implemented in Poland and Europe, the aim of which is to effectively meet the existing needs in the field of passenger transport, and above all to effectively encourage car drivers to use public transport. Introduction of the new solutions in transport is possible due to the growing level of budget expenditure on research and development in the field of transport, telecommunications and other infrastructure. The selected presented innovations in passenger transport effectively improve the quality of travel, increase the efficiency of infrastructure use and contribute to reducing the negative impact of transport on the environment.

Key words: transport, innovations, technological innovations, innovative processes, transport strategies

Synopsis. Przedmiotem badań były innowacyjne procesy o charakterze technologicznym, organizacyjnym, strukturalnym, rynkowym lub socjologicznym. Materiałem wyjściowym do opracowania badanego przedmiotu była analiza dynamiki zmian wydatków na badania i rozwój w zakresie infrastruktury transportowej w Polsce i Unii Europejskiej. Stwierdzono, że w ostatnich dwóch dekadach sukcesywnie wdrażano innowacje w transporcie pasażerskim w Polsce i Europie, których celem było skuteczne zaspokojenie potrzeb w dziedzinie transportu pasażerskiego, a przede wszystkim skuteczne zachęcanie kierowców do korzystania z transportu publicznego. Wprowadzenie nowych rozwiązań w transporcie jest możliwe dzięki rosnącemu poziomowi wydatków budżetowych na badania i rozwój w dziedzinie transportu, telekomunikacji i towarzyszącej infrastruktury. Przedstawione innowacje w transporcie pasażerskim skutecznie poprawiają jakość podróży, zwiększają efektywność wykorzystania infrastruktury i przyczyniają się do zmniejszenia negatywnego wpływu transportu na środowisko.

Słowa kluczowe: transport, innowacje, innowacje technologiczne, procesy innowacyjne, strategie transportowe

Introduction

The developing economies of individual countries, the intensive development of cities and the improvement of the financial situation of the population shows enormous transport demand, which means that traditional investment in infrastructure, services and transport organization does not guarantee satisfying this demand in a satisfactory manner. In many areas around the world you reach the border of traffic and transport intensity, which contributes to significant road congestion and lack of space for new transport infrastructure. In many places around the world the limit of traffic and transport intensity is close, which contributes to significant traffic congestion and lack of space for new transport infrastructure. In addition, energy resources are slowly depleting, on which the majority of mechanized transport technologies are based [Burnewicz 2010].

Eurostat data for 2016 shows that among various means of transport, travellers most often choose traveling by car. As much as 71% of travels were conducted by car. And this number has been steadily increasing over the past two decades. Since 1996, it has increased by over 20%. This causes a significant civilization threat, because the preference of individual car trips over collective transport has a negative impact on the environment. This contributes to air pollution, water pollution, noise emissions and occupying an increasing area of land. Moreover, the increasing land traffic causes a greater number of road accidents, the consequence of which is the threat to human lives.

These worrying effects of transport development lead to the creation and dissemination of modern technologies and a new organization of transport services in a limited economic, natural and social space. The process is easier because we are living in a time of great innovations that are implemented in almost every industry and in every area of life, both in production and in services. The implementation of innovations in transport allows to meet institutional, commercial, individual and group needs, thanks to which it is possible to increase the efficiency and functionality of transport systems, reduce energy demand, reduce harmful effects on the environment and contribute to the development of alternative forms of transport, as well as meet the transport needs of individuals and legal [Burnewicz 2010].

In view of the above, it is important to strive to increase the intensity of research and development in the development of innovative solutions that contribute to increasing efficiency, throughput, reducing unreliability and preventing the loss of time and resources, as well as reducing operating costs. New solutions improve the quality and efficiency of transport and significantly reduce local air pollution and greenhouse gas emissions, contributing positively to the quality of life of residents.

Research goal and methodology

The publication provides a concise description of innovation related activities in passenger transport to identify and evaluate the most promising innovations. The subject of research were innovative processes of a technological, organizational, structural, market or sociological nature. The starting material for developing the studied subject was the analysis of the dynamics of changes in expenditure on research and development in the field of transport infrastructure in Poland and the European Union. A synthetic review of

strategic documents related to the development of transport at national and EU level was also carried out.

The taken up subject is extremely extensive, which is why selected concepts, prototypes and inventions in the field of passenger transport were presented. This way of presenting this issue is helpful in spreading technological knowledge and spreading useful innovations. The analyses were conducted on the basis of source materials presented in publications, scientific articles and internet portals, as well as on the basis of previous research and mass statistics data provided by Eurostat. Methods of processing and interpretation of optional knowledge were used using the descriptive method, the method of descriptive analysis and graphic presentation, as well as literature studies.

Innovation in transport in the light of theoretical considerations

Threats resulting from the intensive development of passenger communication make it necessary to search for new concepts and new means in transport. Therefore, it becomes necessary to intensify innovative activities, which in transport are understood as actions consisting in improving existing ones or introducing new solutions or processes regarding all aspects of changes and contributing to the increase of economic, financial, technical and technological efficiency, the natural environment as well as systems of transport in order to maximize social effects and management results by the public and private sectors [CATI 2012].

Transport innovations should be considered in several areas. They relate to transport technique and technology; planning, organization and management of transport systems, as well as transport financing in the scope of maintaining and modernizing existing resources, as well as new investments in infrastructure and means of transport [Bąk 2016]. From the technology point of view, Bąk [2015] indicates that innovations concern the following areas: automation in road transport, fuel and propulsion technologies, improvement of means of transport, intelligent transport systems, innovations in the field of services and organization as well as infrastructure.

When discussing the types of innovations in transport, the most common is innovation in a technical context. Among them are product and process innovations. In transport, product innovation is understood as the introduction on the transport market of a product whose technological features or purpose are significantly different from previously proposed and supplied products or whose operation has been significantly improved, and at the same time it can provide the recipient (user) with objectively new or increased benefits. In turn, process innovation in transport is defined as the adoption of new or significantly improved methods of operation (processes) in various aspects of transport services, production of means of transport or other transport products, transport management, etc. This may involve changes in the organization, technology, human resources, working methods, equipment or a combination of such changes [Wiszniewski 1999]. Recently, non-technical innovations have also been included in transport innovations. According to the Oslo Manual [2005], non-technical innovation is any innovation activity of individuals that is not associated with the development and introduction on the market of new or significantly changed products or services, and the implementation of new or significantly changed processes. According to this division, we can speak of organiza-

tional and marketing transport innovations. In the case of organizational innovations, we can talk about the implementation of new or significantly improved methods of transport organization. In turn, in the case of marketing innovations, we talk about implementation of new concepts or transport strategies that differ significantly from the methods used so far [Mazur-Wierzbicka 2015].

In some countries, innovation in transport is also considered in the context of more economical use of financial, management and organizational resources. This is due to the increasing transport needs with limited resources [CATI 2012]. In this case, innovations in transport reduce transport costs and time, which causes the users to experience positive emotional feelings, which in turn affects the usefulness of transport products and services, which in turn increases the efficiency of resource use [Lakshmanam and Anderson 2009].

In accordance with Christenssen [2010], who divided innovation into groups, in transport, as in other sectors of the economy, continuation innovations predominate, which mainly contribute to the modernization, improvement of processes and products, e.g. by using batteries in trolleybuses enabling the vehicle to travel along a road section without electric traction. There are also innovations introducing completely new products or processes that can even displace the current technology or product from the market. This is known as innovation that interrupts development. An example would be the introduction, in the past, of internal combustion and electric drives at the expense of steam drives.

Transport innovations are characterized by specific features. Geerlings [1999] emphasizes that transport innovations are focused on individual or collective clients, are quite large and expensive, and in the future will affect other investment projects. This is influenced also by sustainable development as well as they have cooperative character, which means that they do not appear in only one unit. They include institutions and their networks, scientific and research units, public and local administration, government as well as non-governmental organizations and civic initiatives.

In order to develop innovations, innovative activities are carried out through all scientific, technical, organizational, financial and commercial activities. Some of them are innovative in themselves, while others are not new, but they are necessary to implement innovation. Innovative activity is associated with research and development (R&D), which is necessary to develop all innovations [GUS 2018]. Research and development activity is defined as creative work, carried out in a methodical way, undertaken to increase knowledge resources and to create new applications for existing knowledge, which in consequence leads to the introduction into the economy of a "new or significantly improved product, service or process, including the implementation of a new marketing or organizational method that redefines the way the company works or its relations with the environment" [Bukowski et al. 2012]. Conducting R&D activity allows measuring the innovation and innovativeness of the economy of a country, region, industry, sector or a given entity. One of the ways to measure innovation and innovativeness is the analysis of expenditure indicators for research and development activities. The measures of the above R&D indicators include two main groups of indicators [Godecki 2008]:

- cash expenditure on research and development;
- number of persons employed in the R&D sphere.

The above-mentioned indicators inform about how intensively innovative activity is conducted. On the economic scale, the Frascati methodology is most often used to meas-

ure innovation, and the measure used is GERD – gross expenditures on research and development, i.e. the sum of internal expenditure incurred in a given year on R&D by all units conducting this activity in a given country. This is because the Frascati methodology enables multidimensional analyses and comparisons. According to Frascati methodology, expenditure on R&D is classified according to the distance to the economic application of conducted research divided into basic research, applied research and development works, as well as into other classes (according to the criteria: sector in which research is conducted – business, government, higher education, private non-profit; according to the source of funds: domestic and foreign; according to socio-economic goals; according to research areas, etc.) [Bąk 2016].

The place of innovation in passenger transport in Polish and EU strategic documents

An efficient and well-functioning passenger transport system is essential for the inhabitants of the European Union. The EU's transport policy aims to promote clean, safe and efficient traveling across Europe, providing the basis for citizens' right to travel freely throughout the EU (both at work and for recreation). The implementation of this policy is intended to make transport effective, sustainable, safe, reliable and constitute homogeneous European transport area by improving regulation, ensuring a high degree of implementation of EU transport legislation and open and fair competition both in the EU and in relations with key partner countries. This allows creating a modern European transport infrastructure –ensuring effective implementation of the Trans-European Transport Network (TEN-T) financing under the Connecting Europe Facility (CEF) and using innovative financial instruments (such as the European Fund for Strategic Investments (EFSI). The assumptions of the EU transport policy are also an innovative transport sector, which is possible thanks to the effective implementation of funding for research and innovation in the field of transport under the Horizon 2020 program [Eurostat 2019], whose priorities are [European Commission 2019]:

- more sustainable transport: resource-efficient transport that respects the environment;
- improving transport and transport systems: better mobility, less congestion, more safety;
- maintaining transport competitiveness: the European transport industry as a global leader;
- making transport research responsive: socio-economic research and forward-looking activities in policy making.

The key goal of EU policy, however, is to reduce citizens' dependence on private cars to achieve cleaner and more efficient transport in urban areas. The issued document entitled "White Paper on transport" [DG MOVE 2011] emphasized the need to withdraw vehicles fueled with conventional fuels and replace with vehicles with lower emission. In addition, the White Paper contains a strategy for near-zero urban logistics in the EU by 2030. The EU supports a price and market approach towards greener transport, including a new green public procurement system.

Poland, which has been investing significant financial resources in innovative transport from many years, prioritizes the increase of transport accessibility while improving the safety of traffic participants and the efficiency of the sector. This is possible thanks to the implementation of the assumptions of the Strategy for Sustainable Transport Development until 2030. Implementation of the strategy requires undertaking, among others, activities such as: building an integrated and interconnected transport network for a competitive economy or improving the organization and management of the transport system. Public transport is promoted and the safety of traffic participants is increasing. Implementation of the strategy also requires limiting the negative impact of transport on the environment and improving the efficiency of the use of public funds allocated to transport projects.

The strategy also points to modern solutions that facilitate the functioning of the entire transport sector and reduce its negative impact on the environment and climate, so that it is possible to create a sustainable transport system for the country by 2030. Activities in this area should be limited to, among others for the development of innovative ITS technologies, development of intermodal transport infrastructure, digitization of transport services, the introduction of autonomous buses to the market, the use of innovative noise-absorbing road surfaces, with increased strength, less susceptible to abrasion [Ministerstwo Infrastruktury 2019].

In addition to the above-mentioned most important documents supporting the development of innovative transport, there are a number of other treaties, strategies, memoranda, and policies in force within the union, country, voivodship, poviat or commune. All of these documents direct their records towards activities related to the desire to build and operate sustainable and modern transport.

Innovative activity in passenger transport in Poland and the EU

Above, it has been pointed out that one of the ways to measure innovation and innovativeness is to analyse expenditure indicators for R&D. When using the data presented by Eurostat for the analysis, it is necessary to take into account the collective method of presentation of results for transport connected by telecommunications and other infrastructure. Figure 1 presents the share of Poland's budget expenditure against the background of 28 EU countries on R&D in the field of transport, telecommunications and other infrastructure. The data are presented in the calculation of the euro spent per capita. In two decades in the EU, expenditures on research and development in transport is steadily increasing. Since 2000, these expenses have more than tripled, from 1.8 to 5.7 GBP per inhabitant. It should be noted that the most was spent in 2008–2010 form 6.7 to 7.1 GBP per inhabitant.

A similar situation occurs in Poland. Here, the increase in expenditure was even more significant, as research expenditure in the transport sector increased fivefold from GBP 0.75 per inhabitant in 2000 to GBP 4.2 per inhabitant in 2016. However, in the period of 2004–2007 there was a decrease in expenditure in this up to GBP 0.2 per inhabitant.

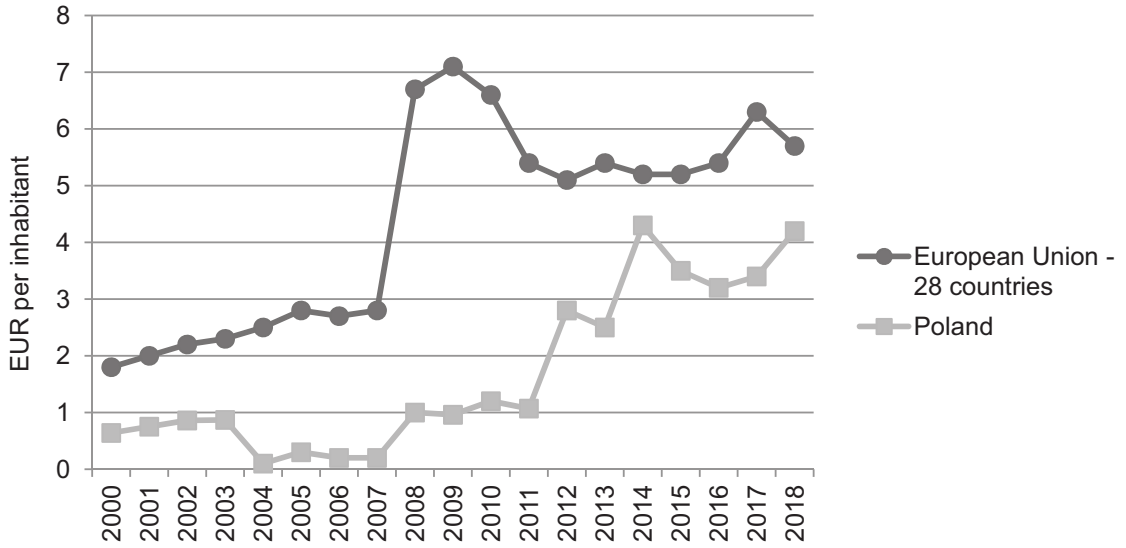

Figure 1. Budget expenditure on R&D in the field of transport, telecommunications and other infrastructure in Poland against the background of 28 EU countries

Rysunek 1. Wydatki budżetowe na badania i rozwój w dziedzinie transportu, telekomunikacji i innej infrastruktury w Polsce na tle 28 krajów UE

Source: own study based on Eurostat webpage https://ec.europa.eu/eurostat/web/science-technology-innovation/data/database [access: 05.11.2019].

In the last two decades, the level of budget expenditure on R&D in the transport, telecommunications and other infrastructure sector in EU countries has been at the level of 1.3–3.8% of total R&D expenditure (Fig. 2). There are two characteristic levels of these expenses. In 2000–2007, the level of expenditure was around 1.5% of all expenditure. In 2008, there was a visible increase in expenses to the level of 3.8%, followed by a gradual slight decrease in expenses to the level of 2.9% in 2018.

In Poland, it can be seen that in the years 2000–2003 and 2011–2018, the level of R&D expenditure in the transport, telecommunications and other infrastructure sectors in general research and development expenditure was higher than the average expenditure in the entire EU. In addition, since 2011, the level of these expenses has been growing steadily and quite dynamically and in 2018 reached 11.2% of all expenditure on R&D. Therefore, a high emphasis is placed on developing innovations in transport in Poland.

Analysing the situation in the scope of budget expenditure on R&D in the field of transport, telecommunications and other infrastructure in individual EU countries, it can be stated that the most budget is allowed in Sweden (Fig. 3). Respectively, GBP 18.9 per inhabitant in 2010 and GBP 16.5 per inhabitant in 2018. Malta and Lithuania spend the least on R&D in transport – around GBP 0.1 per inhabitant.

In 2010, Poland belonged to the group of countries least spending on research in the discussed area, but in 2018 the level of these expenses significantly raised Poland in this ranking. Unfortunately, but it can be seen that in most countries, spending on transport research has fallen in the years analysed. Only in eight countries there has been an increase.

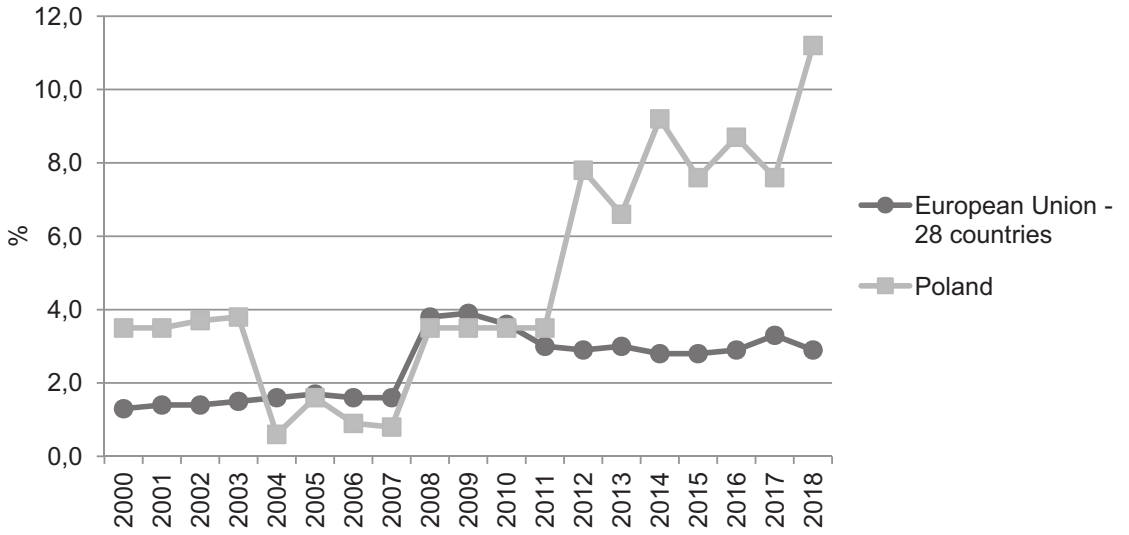

Figure 2. Share of budget expenditure on R&D in the transport, telecommunications and other infrastructure sector in total R&D expenditure in Poland against the background of 28 EU countries

Rysunek 2. Udział wydatków budżetowych na badania i rozwój w sektorze transportu, telekomunikacji i pozostałej infrastruktury w całkowitych wydatkach na badania i rozwój w Polsce na tle 28 krajów UE

Source: own study based on Eurostat webpage https://ec.europa.eu/eurostat/web/science-technology-innovation/data/database [access: 05.11.2019].

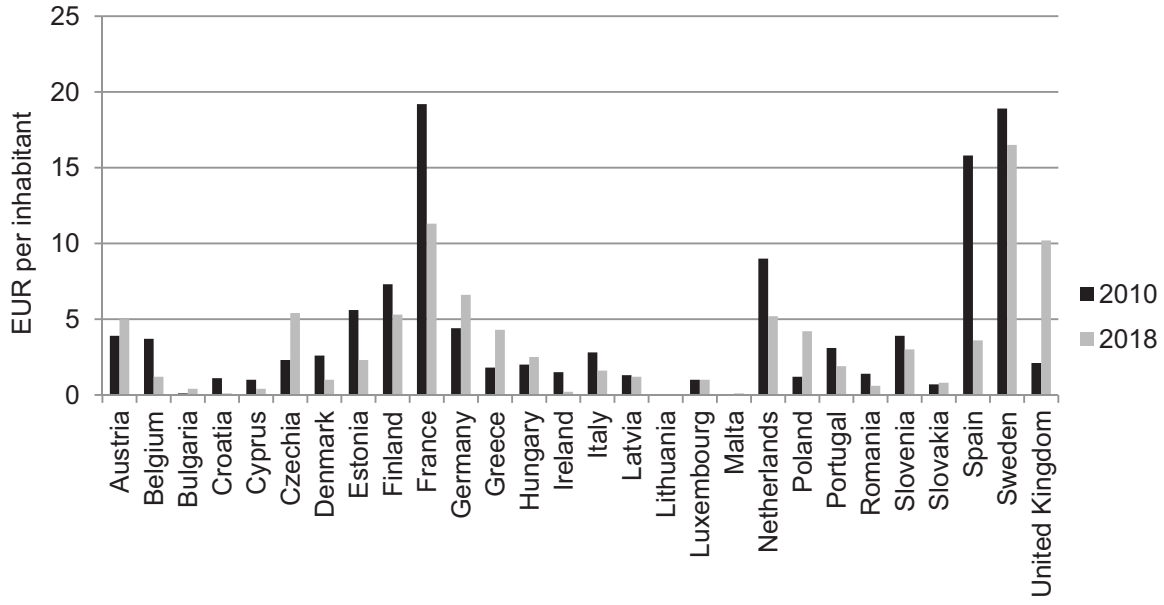

Figure 3. Budget expenditure on R&D in the field of transport, telecommunications and other infrastructure in individual EU countries

Rysunek 3. Wydatki budżetowe na badania i rozwój w dziedzinie transportu, telekomunikacji i innej infrastruktury w poszczególnych krajach UE

Source: own study of the authors based on Eurostat webpage https://ec.europa.eu/eurostat/web/science-technology-innovation/data/database [access: 05.11.2019].

Selected examples of innovative activities in the field of passenger transport in Poland and the EU

The expansion of transport networks contributes to the density of infrastructure, making travel more complicated. That is why more and more technologies supporting intermodality are being developed. An excellent example here is the Intermodal Journey Planning software using internet or mobile applications, which is a good way to plan travel and track disturbances. These applications use big data management technology and provide helpful information to drivers, making travel easier. The Great Britain was a pioneer in the application of this technology. Smart Motorway technology that allows a more even distribution of traffic due to road monitoring, or the use of mobile technology to track traffic data and communication with drivers, as well as smartphone applications informing drivers about the availability of parking spaces to improve parking in cities [PwC 2015]. In Poland, drivers can use similar applications, e.g. Yanosik. Due to interactivity and user involvement, current traffic incidents are always displayed. The application is a great alternative to CB Radio.

For several years, Carpooling has become fashionable, i.e. commuting to work, school and even on vacation. This fashion reached Europe from the USA, where ways to reduce car traffic in polluted and congested cities were sought. Carpooling consists in the fact that in a special application, e.g. BlaBlaCar, the driver reports the route of his journey, along with the number of available seats and the proposed cost of the trip. In turn, the potential passenger chooses from the offers presented the most favourable for him and reserves the journey. Such joint commutes contribute to the limitation of cars on the roads[1].

In recent years, many local governments have invested in Intelligent Road Traffic Management Systems. A good example is the Area Traffic Control System (SOSRD – System Obszarowego Sterowania Ruchem Drogowym) built in 2013 in Rzeszów. SOSRD affects the improvement of getting around the city. It consists of the following elements [Gmina Miasto Rzeszów n.d.]:

- traffic light control system that allows to maintain traffic flow and reduce waiting times at crossroads to a minimum;
- priority system for public transport vehicles, allocating first the right of transit to public transport;
- driver information system using variable content signs will allow for quick informing about difficulties, changes in traffic organization or recommended detours.

In the 21st century, innovations in fuel and propulsion technologies are dynamically implemented. The term electromobility has become the most popular concept in the last five years. The leaders in Europe are the Scandinavian countries, which are the most advanced in the implementation of electric drives in cars and buses. In such vehicles (BEV – Battery Electric Vehicle), electric drive is the only power source. This solution reduces exhaust emissions to zero only at the place of use of the vehicle, because the analysis of the "drawn bill: should take into account the emissions generated in the process of electricity production. And in many countries, electricity is produced mostly in coal-fired power plants. In passenger transport, the energy source for electric motors is energy accu-

[1] www.blablacar.pl [access: 06.11.2019].

mulated in high-power lithium-ion batteries. Charging batteries in electric buses: through a pantograph, induction loop and plug-in, i.e. a battery charger. This system is constantly improved, and the main barrier to the implementation of this drive is the cost of purchasing vehicles, as well as the construction of the necessary charging infrastructure. It is estimated that the cost of vehicles is almost twice as high as those powered by internal combustion engines [Sojka et al. 2016].

The innovative technology in transport is hydrogen drive. Fuel Cell Vehicles (FCVs) contribute to reducing emissions to the atmosphere. The product that results from the "combustion" is steam. It is a zero-emission transport. Hydrogen can be burned in a traditional internal combustion engine or used in fuel cells to generate energy that drives the engine [Burnewicz 2010]. The barrier to the popularization of this fuel is the negligible number of hydrogen distribution points.

In recent years, more and more self-governments of various European cities are analysing the possibility of implementing autonomous technologies in passenger transport. One of the first cities that has been testing small autonomous buses since 2019 is Vienna. Currently, small, 10-passenger vehicles are used, which use GPS to determine their position with an accuracy of 3 cm. Although the intention to build autonomous vehicles was to travel without a driver, every ride is supervised by a person. Another negative feature is the low speed of travel, because autonomous buses currently run at a maximum speed of up to 20 km/h [Urbanowicz 2019].

Another solution is monorail, which is a special kind of system similar to the metro – with a separate infrastructure, moving on a single rail. It is an underground class system, its unique feature is that it is mounted on elevated supports about 5–6 m high. Therefore, it provides high performance, maximum safety, and at the same time does not take up space that is lacking in cities. Monorail has similar parameters, traffic rules and level of safety as the underground, but the costs associated with the construction of these elevated structures are several times less than tunnelling [forsal.pl 2019]. The most advanced city in Poland, that has already developed the concept of locating a monorail train system, is Rzeszów. Subsequently, this system intends to be built by the Górnośląsko-Zagłębiowska Metropolis. The main barrier in the implementation of such an investment is the lack of legal regulations in Poland, allowing this type of transport for use, as well as high investment costs.

When discussing innovations in passenger transport, ambitious plans to build high-speed rail in Poland, an investment accompanying the creation of the Central Communication Port, cannot be missed. The plans assume the creation of so-called spokes, where from the central airport, completely new communication routes will be built in every direction of the country. It is assumed that by 2027, 1,100 km of double-track railway lines and 500 km of single-track railway lines will be built. The trains are to travel at speeds up to 250 km/h, and the journey time from the most distant provincial cities to the centre of Poland is to be two hours. The exception is to be Szczecin, where the trip is to last over three hours. Despite the fact that high-speed railways have been operating in Europe and the world for many years, this will be a long-awaited innovation on a national scale, as trains currently run on average at 120–160 km/h, and only on small sections from Warsaw to Gdańsk with maximum speed up to 200 km/h [Karnaszewski 2019].

Summary and conclusions

In the last two decades, innovations in passenger transport have been successively implemented in Poland and Europe, the aim of which is to effectively meet the existing needs in the field of passenger transport, and above all to effectively encourage passenger car drivers to use public transport. The introduction of new solutions in transport is possible thanks to the growing level of budget expenditure on research and development in the field of transport, telecommunications and other infrastructure. Only thanks to the close cooperation between science and business practice it is a condition for increasing innovation and implementing inventions. Thanks to this, the quality of passenger transport services is improved, new passengers are acquired, the satisfaction of current users is increased, and as a consequence the share of the passenger transport market is increased. In addition, congestion is reduced as well as a negative impact on the environment. People's quality of life is improving.

Despite favourable trends, it becomes necessary to further intensively develop completely new, breakthrough technologies that will enable further social and economic development. We should move away from oil and go into electromobility technologies. Thanks to material engineering, large energy resources can ultimately be stored in batteries, and fuel cells based on different forms of hydrogen should be widely used in high-capacity vehicles. In turn, the governments of individual countries must respond quickly to emerging technological solutions and change legislation so that the resulting innovations can be quickly implemented into practice. The European Union should continue its policy on sustainable transport, which makes it possible to financially support many institutions responsible for passenger transport. Due to such activities, the perspective of ecologically clean, safe and energetically sustainable transport is becoming more and more close and realistic.

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