

Innovations in Local Public Transport-Significance for the Local Community

INNOVATIONS IN LOCAL PUBLIC TRANSPORT - A THEORETICAL APPROACH

Eurostat statistics indicate the persistent level of car use in the EU in the last 10 years. In 2014, passenger car transport accounted for 83.4% of land transport (measured by the number of passenger kilometres), in the years 2004–2014 the use of cars was in the range of 83–83.7%. There are visible changes in the use of other means of transport, in the case of trains it is an increase from 6.7% in 2004 to 7.6% in 2014, while the use of bus and trolleybus transport in the same period decreased slightly from 9.9% to 9.1% (Eurostat, 2017). In the context of urban traffic congestion, transport congestion, and environmental pollution, it is extremely important to promote mass transport among residents in order to improve mobility and reduce environmental pollution. Many cities plan and take initiatives to limit individual car transport in favour of public transport, cycling, and pedestrian traffic.

Public transport, cycling, and pedestrian traffic will become an alternative to owning and using one's own car only if those modes of transport are well organised, integrated, and accessible to passengers (Salonen, 2018; Buehler and Pucher, 2011). Data from the Quality of Life Survey, Eurobarometer on public transport indicates that it is popular especially in large European cities. Almost 20% of the residents use public transport in almost all cities studied, which results, on the one hand, from the quality and accessibility of those services and their territorial integration (e.g. within metropolitan areas), and, on the other, from urban congestion. Public transport has been modernised in many cities, and the process covered both the rolling stock and the transport infrastructure (UN-Habitat, 2016). The process was supported by EU funds. In 2007–2013, public transport entities from the European Regional Development Fund and the Cohesion Fund in the EU28 spent 0.8 Euros per EU citizen per year (Tab. 1) (UN-Habitat, 2016). Metropolitan regions were the main recipients of the interventions fulfilled in order to improve mobility, and reduce environmental pollution.

Annual per capita spending	Road transport	Railway transport	Water transport	Public transport	Multimodal transport	Air transport	Bicycle transport	Smart
Capitals of metropolitan regions	8.9	6.6	0.5	1.3	2.2	0.3	0.1	0.1
Outside of capitals in metropolitan regions	10.3	6.0	1.3	0.9	0.4	0.8	0.1	0.2
Outside metropolitan regions	21.4	8.2	1.2	0.4	0.5	0.4	0.3	0.1
Total	14.7	7.0	1.1	0.8	0.7	0.6	0.2	0.2

Source: UN-Habitat, 2016, p. 127.

Most public transport research focuses on economic issues, and the impact of public transport services and their privatization on the costs (Alexandersson *et al.*, 1998), efficiency (Boitani *et al.*, 2013; Pina and Torres, 2001; Egmond *et al.*, 2003), and the quality and availability of services (Fiorio *et al.*, 2013). The issue of innovativeness of public transport is also important (Ongkittikul and Geerlings, 2006). In order for the role of public transport to increase further it is necessary to implement innovative solutions that respond to environmental challenges and problems, to integrate transport modes, and to increase mobility. Innovation in public transport can be of different character and concern for specific facets of the service. Public transport has a technical dimension that applies to the means of transport, technological solutions used in the field of drivetrains, traffic control systems, and transport infrastructure. The process of delivery of the service is another dimension; it applies to the recipient expectations, ensuring the coordination and continuity of the process. The managerial competences of the operators providing public transport services, regulatory system, and adopted priorities in transport policy are yet another element of the service. Considering the above-mentioned components of public transport, innovation can be defined as a change affecting one or several of the mentioned feature vectors. On that basis Ongkittikul and Geerlings (2006) distinguished the following types of innovations in public transport: endogenous service innovations that apply to the development of competences and technical innovations, and exogenous service innovations generated by external factors, including intervention by public authorities.

The process of generating and transferring innovations in public transport is of interest to the EU, which undertakes a number of initiatives in this area. References to this issue could be found in the Urban Transport Package 2013 of the

European Commission (Urban Mobility Package 2013), which proposed measures for urban mobility supporting sustainable urban transport. One of the areas of the package was research and development within the framework of the CIVITAS 2020 initiative, under which cities, institutions, scientific units, and others will be able to develop and test new solutions in the field of urban mobility. The Clean Power for Transport package and the Intelligent Energy Europe (STEER) program are aimed at increasing the use of alternative fuels, also in public transport. The European Commission is also working with Member States on implementing intelligent transportation systems (ITS - travel information, traffic management, smart tickets, and urban logistics), which are essential for increasing safety and addressing issues related to emissions and congestion. Innovative solutions are also supported by the EU's through the promotion of sustainable urban transport plans, of cooperation in this area, and an observatory for sustainable urban transport. Innovative public transport solutions have also earmarked funding under Horizon 2020 to transform the European transport system into a more efficient one that would provide jobs and more efficient utilisation of resources. In the period 20014–2020, 6.3 billion Euros were allocated for that purpose.

An important factor generating innovative solutions in public transport is the pursuit of sustainable development (Tab. 2). In that context, the concept of sustainable transport is important, which means the establishing of the transport system, including the types of transport used, which do not threaten human health and natural ecosystems (Sokołowicz and Przygodzki, 2016). That results in the introduction of environmentally and user-friendly eco-innovations. Eco-innovations are new or improved socio-technical solutions that protect resources, mitigate environmental degradation, and/ or recover value from substances which had already been used in the economy (Jesus and Mendonça, 2017). In public transport, those will be related to low-emission mobility solutions.

The pursuit of public transport in line with the concept of sustainable development was started by numerous program documents developed within the framework of EU and global policies. The 7th EU environmental action program postulates, e.g. the development of an innovative approach to urban public transport and mobility. The need to develop efficient public transport and to promote ecological transport have been included in the Charter of European Cities and Towns Towards Sustainability. In turn, the UN General Assembly in September 2015 adopted the “2030 Agenda for Sustainable Development” which defined the goals of sustainable development. Sustainable transport is included in 7 out of 17 goals.

Many authors indicated that eco-innovations generate not only ecological but also social effects (Boons *et al.*, 2013, Carrillo-Hermosilla *et al.*, 2009; Kunapatarawong and Martínez-Ros, 2016; Rennings, 2000). Lin and Zheng (2016) emphasized the importance of eco-innovations for improving the quality of the environment but also for economic development. Eco-innovations are not only technological solutions that are beneficial for the environment (such as ecological powertrains that reduce

emissions), but also can be a factor in the transformation of the value chain (Andersen, 2008; Kemp, 2010), initiating the recirculation and recycling of resources (Clark *et al.*, 2016). Eco-innovations in that sense become a generator of circular economy processes. Kunapatarawong and Martínez-Ros (2016) proved that such innovations can have an impact even on employment. In connection with the above, it should be recognised that innovations in public transport in the field of low-emission mobility are part of the broader issue of circular economy.

Table 2. Types of innovations in public transport in the context of the latest development concepts

The concept of development	The nature of innovation	An example of innovation in public transport
Sustainable development	Eco-innovations – innovative solutions favouring the maintenance of balance in the ecological and socio-economic system, ensuring sustainable development, reducing environmental burdens.	Buses with electric, hybrid drive, reducing greenhouse gas emissions
Circular economy	Innovations initiating recirculation and recycling of resources	Organic bio-powered buses that allow the reuse of waste
Smart city	Technological urban innovations – innovative technical solutions using modern information and communication infrastructure and data management	Autonomous vehicles – automated driverless vehicles Passenger counting systems used for transport planning, occupancy systems and displaying information on the distribution of passengers in wagons / buses used to control the flows of passengers at bus stops and stations Communication systems between V2V vehicles, vehicles and V2C cloud, vehicles and V2I infrastructure. Systems for monitoring passenger preferences in the field of mobility
Crowdsourcing	Service innovations in which the client plays a special role as a prosumer, a consumer and co-creator of a solution	Personalised travel router

Sources: own work.

Another concept that is a source of innovation in public transport is the idea of a smart city, also referring to the assumptions of sustainable development. It is understood as a space creating conditions for a high quality of life in which services are provided on many levels of community and economic life on the basis of

existing infrastructure and IT solutions (Chourabi *et al.*, 2012). One of the seven qualities of a smart city is intelligent transport and communication. It assumes achieving sustainable development by optimising transport solutions, taking into account technological, social, economic, and environmental challenges (Zawieska and Pieriegud, 2018). Thanks to that, cities should become enormous networks of high-speed connections, enabling the merging and moving of various resources in time and in space (Nowakowska, 2015). Additionally, a smart environment includes solutions that optimise energy consumption, including through the use of renewable energy sources and energy-saving technologies, as well as activities reducing the emissions of pollutants into the environment. Due to the development of the smart city idea, a special type of innovation can be distinguished: technological urban innovations (Meijer and Thaenes, 2018).

The idea of crowdsourcing is connected with the concept of a smart city. It means the mobilisation of knowledge dispersed in a crowd (Zhao and Zhu, 2014), stimulating people's creativity through ICT technologies and combining the roles of city users with the role of co-creators (prosumers). The main assumption of crowdsourcing is to recognise a resident as the source of knowledge about a city, as a user of urban space. As a result of the cooperation between residents, municipal authorities, entrepreneurs, research centres, and of combining different perspectives and knowledge it is possible to co-create innovative ideas and solutions for the problems in a city (Papadopoulou, 2017). It is a tool with strong potential for creating innovations in smart cities. In public transport the idea of co-creation can be used to design transport services by their clients (individual prosumption).

Some innovations result from the need to improve the travel process, which consists of waiting, getting on and off a vehicle, moving on the platforms, and traveling. Management solutions for passenger flows are aimed at loosening bottlenecks and congestion (especially at peak hours – in the morning and the afternoon).

3. INNOVATIONS IN PUBLIC TRANSPORT - GOOD PRACTICES

3.1. Bio Bus, Poo Bus¹

Big cities nowadays have problems with increasing air pollution and smog. Buses fuelled with renewable energy (biomethane) have become the answer to this situation, contributing to the reduction of harmful emissions. The pioneering pro-

¹ Internal documents of the organization under study.

ject of GENeco assumed the introduction of the Bio-Bus into public transport, which is fuelled by gas obtained through the treatment of sewage, food waste from households, and manure. In nature, such a raw resource can be found in marshes and peat bogs. The rolling stock was introduced in Bristol in 2015, when the city served as the “Green European Capital”. The project was supported by the local community and environmental organizations, mainly due to the environmental benefits of such a solution. It also minimizes the health problems of the local community caused by air pollution. Such a bus can be driven in with a full tank for 300 km. The gas tank is installed on the roof of the vehicle. It was calculated that the necessary amount of fuel is produced from domestic waste annually by five residents.

Another undertaking of that organization was the work on the utilisation of the gas in households, which would be a practical example of circular economy.

Biomethane has the same composition and properties as fossil fuels and can be a substitute for natural gas in public transport. Raw fuel comes from various types of waste and manure.

The following points summarise the production rules for that ecological energy source:

- waste is processed and pressed into a series of anaerobic fermentation cells,
- leftovers are heated to 32–42°C temperature and then stored in fermentation chambers for 12–18 days,
- microorganisms decompose biodegradable matter due to a lack of oxygen,
- a small amount of propane is added to the resulting raw product, which enriches its composition and calorific value,
- the final product undergoes a number of quality checks before being released for local distribution.

The use of such a fuel undoubtedly benefits the environment. When compared with widely used diesel, one can see that:

- emissions of solid particles are reduced to 97% – a microscopic substance that passes easily from the lungs to the bloodstream. According to research, one in twenty people living in urbanised areas will die prematurely, which is directly related to dust pollution (Xia *et al.*, 2015),
- nitrogen oxides emissions have been reduced by 80–90%. Those gases contribute to the formation of acid rains, urban smog, and they adversely affect the development of vegetation,
- “wheel-to-wheel” analysis, i.e. from the fuel production stage, through production, storage, transport, to its use in buses, indicates that CO₂ emissions in bio-gas-powered buses can be reduced by 68% to 82% compared to traditional diesel. The situation is presented in Tab. 3, where carbon dioxide emissions in various types of vehicles using selected types of fuels are listed.

Table 3. Annual wheel-to-wheel GHG emissions for selected types of road vehicles

Vehicle type	Annual well-to-well CO2 emissions (tonnes per year)			Percentage in WTW emissions	
	Petrol/Diesel	Natural Gas	Biomethane	Natural gas vs petrol/diesel	Biomethane vs petrol/diesel
Passenger car (petrol)	1.70	1.39	0.20	-18%	-88%
Passenger car (diesel)	1.31.	1.39	0.20	+6%	-85%
LCV	3.98	4.28	0.82	+8%	-79%
Small rigid truck	18.07	20.43	4.91	+13%	-73%
Large rigid truck 26 t	48.21	55.94	10.61	+16%	-78%
Articulated truck (>32t)	135.38	136.23	82.00	+1%	-39%
Bus	57.53	60.96	10.10	+6%	-82%
Coach	46.14	53.12	9.60	+15%	-79%

Source: The role of natural gas and biomethane in transport sector, https://www.transportenvironment.org/sites/te/files/publications/2016_02_TE_Natural_Gas_Biomethane_Study_FINAL.pdf (15.01.2018).

As presented in Tab. 3, carbon dioxide emissions in the wheel-to-wheel cycle lean towards bio-ecological fuels in each vehicle type. The discussed eco-innovations are of a technological nature. They can also be seen as an example of conceptual innovations because they result from the changes in the views on the decarbonisation of transport through electro mobility. The effects of implementing electro mobility in reducing air pollution depend on the structure of resources used to produce electricity. The development of biogas drivetrains seems to be a competitive alternative in this respect.

3.2. Driverless Buses²

Another innovative solution in public transport are automatic driverless buses. The reason for implementing such a solution in 2015 was primarily to improve the quality of the services provided to local communities in low-urbanised areas. It is also important to reduce the costs associated with the remuneration of the person

² Internal document of the Department of Transport.

driving the vehicle. Due to the reduction of fees, the frequency of buses can be higher, which is especially advantageous in rural areas, where timetables are often not satisfactory for the residents. That solution contributes to a better adjustment of the frequency of the routes to the actual needs of the local community. However, there are doubts and questions about such a solution. If a bus has an accident, what will happen, who will notify the service when there is no driver in the vehicle? It is also necessary to amend vehicle insurance regulations, which until now have not included the payment of compensations for automatically-controlled buses. It is not a small challenge to convince potential clients about the benefits of such an innovation. The main concern is the safety of the people traveling by the vehicle as well as other road users (drivers of agricultural machinery, cyclists or pedestrians traveling on local roads).

Innovations related to unmanned buses can be subjected to a SWOT analysis, presenting the strengths and weaknesses, as well as opportunities and threats of the described project, which is presented in Tab. 4.

Table 4. SWOT analysis of driverless busses

Strengths	reduction of transport costs, originality of the solution, more frequent courses, better adjustment to the needs of final recipients
Weaknesses	no organisations that could be compared, high costs associated with testing and implementing automation
Opportunities	modern navigational systems, good quality of public roads, automation, public's openness to innovative solutions
Threats	competition, public concerns about safety, lack of legal solutions regarding insurance, social exclusion in terms of virtualisation

Source: own work.

Also in this case, one can talk about technical innovations but also about process innovations which result from a change in the way the service is delivered. It is also an example of an evolutionary innovation, where the change in the way a service is provided relates to the current group of users.

3.3. Real-Time Traffic Updates³

Another proposal to improve public transport in urban areas is the solution for informing residents and road users about the current traffic conditions in the area. Such messages are presented on digital boards placed on the rear, exter-

³ Internal document of the Department of Transport.

nal walls of buses. The solution is primarily aimed at reducing congestion in London, which has had a positive impact on increasing the efficiency of road users' commutes and reducing the pollution of the environment in a given area. The vehicles have been equipped with Equitech IT Solutions electronic boards, which use GPS technology to provide accurate traffic information. The data is collected and updated from a network that is controlled 24 hours a day by the traffic control centre. The idea behind the solution was taken from taxi companies. Their cars are fitted with similar boards (of course much smaller), on which advertisements are displayed.

It is a typical technological urban innovation, part of the smart city concept, open data management in particular.

3.4. Green Areas in the London Underground

Passengers waiting for the arrival of the underground very often gather in one part of a platform, despite the fact that the platforms are quite long. Such an excessive crowd makes it difficult to embark and disembark the carriages, causing dangerous situations related to the possibility of mutual deduction, fall or crush. Green painted lines graphically indicate the places where one can stand and wait for the arrival of the underground, and where the wagon doors will open. Travellers receive information that they should not stop in the area of the green line because they are intended for people who disembark and leave the underground station. Additionally, graphic signs have been placed on the walls with the inscription saying not to wait on the green lines. The situation is presented in Fig. 2 and 3.

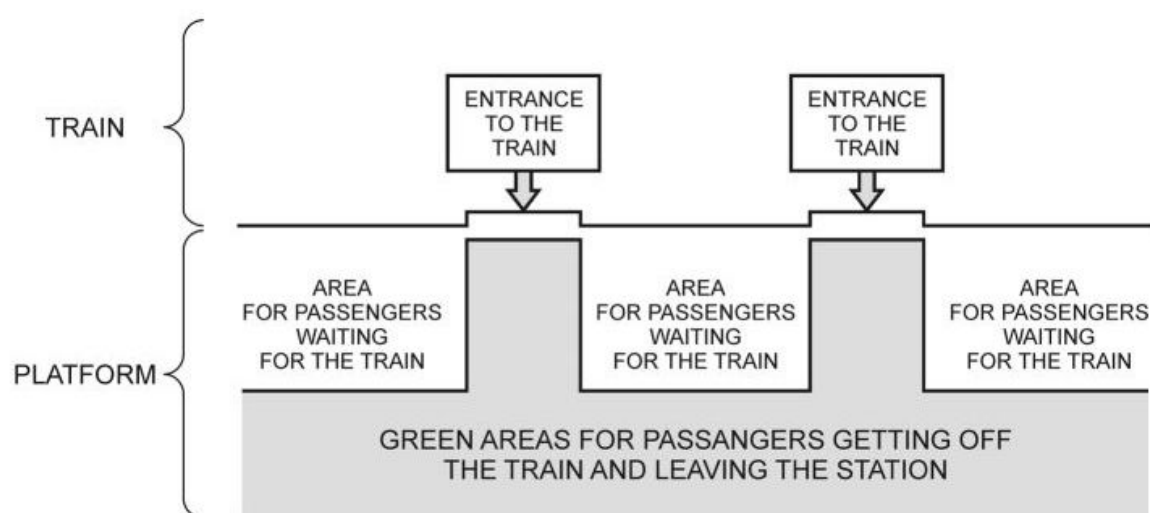


Fig. 2. Green areas in the London underground

Source: own work.

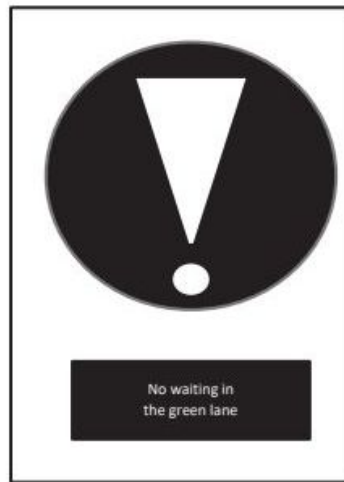


Fig. 3. Signs on the walls asking the passengers not to wait on the green lines

Source: own work.

In addition to graphic devices, information about the need to move along the track not causing unnecessary obstructions is aired on the PA. However, the latter solution has been in operation for a few years without any major effects. That is due to the fact that a significant part of the society better absorbs visual and graphic messages. The effectiveness of the introduced improvements and the preservation of recorders are controlled live, thanks to the installed cameras and monitoring. Transport For London hopes that the solution will be particularly helpful during the morning and afternoon rush hours. One should think about choosing the colour of the lines painted on. It is known that red and orange are identified with something that should be avoided, while green is rather associated with something that is inviting and friendly. Therefore, travellers may reflexively fall into the wrong places because green will be associated with security and the permission to stay in the place. Tests are being conducted at London's King's Cross and Victoria stations. Their results are to be known and made public in spring of 2018. When the experiment proves positive, the city authorities plan to extend such graphics to other mayor stations in the capital of Great Britain.

The presented innovation is of a conceptual and incremental nature. It involves introducing improvements without changing the way the service is provided to an existing group of recipients.

3.5. Crowding indicators

An innovation in informing passengers of the London underground about the current congestion of oncoming train cars is also currently being tested. The program assumes that the rolling stock being used should be modernised and equipped with data loggers

that read the number of travellers. The solution is to lower the number of passengers in a car, and to better position those waiting so that they could intentionally enter the less crowded parts of the underground. The information is displayed on the electronic notice boards about the time of arrival of a train. The code used in this solution consists of colours (red, yellow, green) and notifications about the level of congestion in a train car. A graphic presentation of the current congestion of an underground train is depicted in Fig. 4. That is a typical incremental technological innovation.

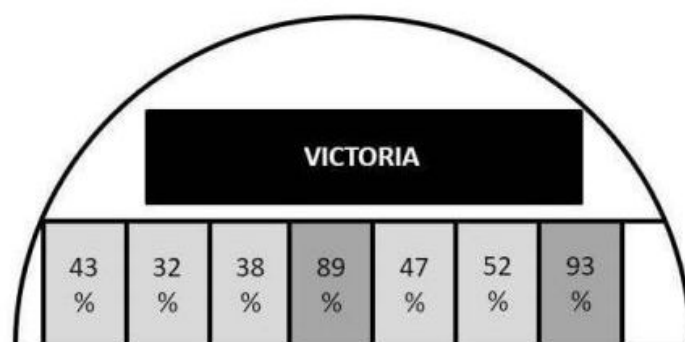


Fig. 4. Crowding information on screen

Source: own work.

The main benefits of using the solution are:

- increasing the throughput thanks to a smoother and faster embarking and disembarking the rolling stock,
- help in making better decisions for passengers choosing a less crowded underground car,
- greater travel comfort,
- minimising bottlenecks arising from embarking and disembarking the cars.

4. CONCLUSIONS

The quality of public transport services has a significant impact on consumer decisions regarding the choice of the way they travel. For that reason actions leading to its improvement are necessary. The means for achieving it are innovative solutions for various vectors of transport service features (Tab. 5). In addition to advanced technical innovations, changes not related to large expenditures and the use of advanced technologies are also possible.

Table 5. Directions of selected innovations in public transport in the local community contribute to meeting the needs, and respond to social expectations

Innovation	Environment	Health	Mobility	Security	Economic aspects	Social aspects
Bio bus, poo bus	Reducing greenhouse gas emissions	Reducing the frequency of respiratory and circulatory problems	They contribute to the increase of mobility, also over long distances	It affects ecological safety	Reduction of travel costs. Repeated use of resources in the economy, effective resource management	The community provides resources for the production of bio fuel Increased ecological awareness Active participation in local development
Driverless buses	–	–	They contribute to the increase of mobility thanks to the automation of the vehicle and its optimal use	They reduce the sense of safety of travellers as well as other road users No availability of insurance offers for this type of vehicles	Limiting the costs associated with driver compensation The system of individual ordering of a vehicle contributes to the reduction of costs related to the incomplete use of seats in buses	Positive reception of innovative projects by the local community. Better adjustment of travel frequencies for travellers
Real-time traffic updates	Impact on pollution reduction	Reduction of exhaust emissions	Important for road users. It gives them the opportunity to choose less crowded streets. It results in the reduction of travel time	They help reduce street congestion, and improve road safety.	Individual savings for drivers as well as for city administrations related to the elimination of the effects of air pollution	Improving the comfort of travel Access to up-to-date information An increase in the number of traffic sources related to congestion in a city Placing plates at the rear end of a vehicle contributes to better information reception

Innovation	Environment	Health	Mobility	Security	Economic aspects	Social aspects
Green areas in the London underground	–	–	Improving the flow of passengers at stops and stations	Increased safety, especially when embarking and disembarking a vehicle	Reduction of the costs related to passenger exchange	Time saving for passengers Effective lapping with information to passengers
Crowding indicators	–	–	Improving the flow of passengers at stops and stations	Increased safety, especially when embarking and disembarking a vehicle Smaller congestion of wagons reduces the risk of accidents during, e.g. sudden braking	The ability to predict the number of wagons needed to carry passengers at certain times of the day	Increased comfort of travel

Innovations can contribute to the reduction of negative phenomena in various areas, such as the environment, health, mobility, security, economic issues, and social aspects. The greater the complexity of the introduced changes, the more they contribute to meeting the needs, and respond to social expectations.

The examples of innovations in public transport presented in the article include service innovations of an endogenous character, mainly resulting from the application of new technical solutions. Usually, they are incremental so the solutions implemented do not change the way the service is provided. Their source is often a change in views that is a consequence of new knowledge.

The main conclusion from the analysis is that the introduction of innovations in public transport, in particular their compilation, significantly affects the local community. It mainly applies to the access to information which helps one save time, increase mobility, travel comfort, adjust the organisation of transport to the needs of the travellers, and increase travel safety or its personalisation. Fostering the ecological awareness of travellers is also important.

Innovations in public transport largely result from the pursuit of sustainable development, in particular a reduction of pollutant emissions and recycling of resources, as well as the factor of economic development. Therefore, they are a tool for achieving the objectives set out in the strategies for sustainable development and the decarbonisation of transport. In turn, the use of smart ICT in public transport is particularly important for the comfort of passengers.