

Transport decarbonisation in Poland: Beyond Best Practices national technical report

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Wise Europa

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Summary

This national technical report analyses the state of passenger transportation in Poland and highlights the key policy initiatives needed to reduce emissions in the public transport sector. The report finds that Poland is highly dependent on private car usage: in 2021, passenger cars accounted for 80% of the modal split of passenger transportation.

Suburbanization, poor connectivity of public transit to rural areas, and an increase in per capita income have all contributed to the prevalence of private car use in Poland. Additionally, there are many barriers to building effective public transport supply, such as a high cost of financing, unstable legal and financial environment, and lack of cooperation between local governments at various levels.

To address these challenges, the report proposes a variety of Poland-specific solutions. First, long-term urban planning efforts must be made to create walkable cities of short distances. Numerous Polish cities are already models for creating pedestrian-only spaces; they must continue to design urban spaces that discourage private car use. Polish cities must also integrate cycling into existing transportation infrastructure, such as by creating bike-only lanes. Furthermore, railway infrastructure must be designed in such a way that it connects to smaller, urban cities as well. Poland should continue the process of electrification of bus fleets. By implementing these measures, Poland can develop an efficient and sustainable, public transportation sector and accelerate much needed reduction in emissions.

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Introduction

Passenger transport in Poland is dominated by personal cars, which make up nearly 80% of both the modal split and total emissions from passenger transport (Climate Analytics, 2023). As incomes have risen over the past two decades, Polish consumers have increasingly purchased personal cars. This trend has been strengthened by a strong import market of older and affordable vehicles from Western European states. Relatively weak rail connections to small and medium cities and towns, as well as slow decarbonisation of the transport sector continue to challenge emissions reductions.

Passenger transport is influenced directly through transportation policy, as well as through both climate and urban development policies. The National Transport Policy 2006-2025 acts as a framework document to guide transportation development and planning through both long-term strategies and by setting expectations for future policies. Other key policies are the National Urban Policy and Poland's NECP. Suggested best practices for Poland include further integration of rail and public transport, as well as specific measures to support cycling infrastructure and the electrification of Poland's bus fleet.

Transport governance

Poland's national governance framework for transportation and decarbonisation is mainly a series of short- to medium-term packages targeting decreased emissions and promoting sustainable development to facilitate long-term growth and improved quality of life. These packages generally address three main policy areas: transportation, urbanisation, and energy consumption. In addition, transport and emissions-related topics have been discussed in other important strategic documents adopted on national level.

General strategic documents

"Strategy for Responsible Development" until 2020 (with a perspective until 2030)

The "Strategy for Responsible Development until 2020 (with a perspective until 2030)" is a medium-term plan for the development of the country, the main goal of which is "creating conditions for increasing the income of Polish residents while increasing cohesion in the social, economic, environmental and territorial dimensions" (Council of Ministers of the Republic of Poland, 2017). The document draws attention to the rapid increase in passenger cars, whose average age, higher than the average for EU countries, is a source of additional air pollution and CO₂ emissions. The progressing suburbanisation of large urban centres was also indicated. Other challenges mentioned were the lack of a spatially and functionally integrated public transport offer, still low use of Intelligent Transport Systems (ITS), insufficiently developed infrastructure and lack of modern, low-emission rolling stock.

For urban mobility, the document Strategy focusses on development of "integrated public transport systems" in cities that centre around low emission transport such as rail and electric buses. The transport system would include integrated and improved infrastructure for cycling and walking in order to strictly limit individual car use in cities. Rural areas would see construction and modernisation of transit infrastructure and improvement of transport services to improve connectivity (Council of Ministers of the Republic of Poland, 2017).

State Environmental Policy 2030

The State Environmental Policy 2030 (PEP2030) extends the aforementioned Strategy in the areas of climate, environmental protection, and water management. It was to be the basis for investing European funds in the 2021-2027 period. The main objective of PEP2030 is to develop the environment's potential for the benefit of citizens and enterprises. In the transport field, the Policy indicates the need to support the reduction of emissions from road transport and developing low- and zero-emission transport (Council of Ministers of the Republic of Poland & Ministry of Climate, 2019).

National Recovery and Resilience Plan

The National Recovery and Resilience Plan (KPO) is a development plan that defines goals related to the reconstruction and creation of Poland's socio-economic resilience after the crisis caused by the COVID-19 pandemic, as well as reforms and investments to achieve them. The document is the basis for applying for support from the European Recovery and Resilience Facility. One of the six components of KPO implementation is green, intelligent mobility. The framework will include investments in rail and road transport infrastructure, public transport rolling stock and road safety improvement (Ministry of Development Funds and Regional Policy, 2023).

Regional- and urban-level strategic documents

National regional development strategy (2019)

The strategy is the primary document of the state's regional policy until 2030. The challenges include, among others: adaptation to climate change and mitigation of threats to the environment. One of the key activities described in the development strategy is improvement of existing road infrastructure to support road safety and communication.

According to the strategy, the dynamic increase in the number of cars is driven by increasing suburbanisation and the need for people to commute daily to work and school. Traffic levels, air and noise pollution, and travel time have all increased as a result (Republic of Poland, 2019a). In 2010-2012, further development of public transport helped slow the shift from public transport to private vehicles. Thanks to the investments put in place, it became possible to carry out a large-scale replacement of rolling stock and modernisation of infrastructure in public transport.

Many rural and urban-rural communes still need more public transport solutions. Poorly developed transport infrastructure in rural areas is currently one of the most critical barriers to their development in Poland. Passenger railway transport was given particular importance in terms of improving accessibility to regional urban centres.

The National Urban Policy 2030

The National Urban Policy 2030 (KPM 2030) adopted by the Council of Ministers in June 2022 is the one of the most recent strategic policies dealing with the transport sector in Poland. The national urban policy deals with "facing development challenges and building conditions for strengthening the capacity of cities and functional urban areas for sustainable development, improving residents' quality of life and building resilience to observed climate change" (Ministry of Development Funds and Regional Policy, 2022). KPM2030 identifies critical challenges for sustainable urban development and outlines some high-level solutions.

The eleven critical challenges for cities and their functional areas also included ensuring a sustainable and integrated urban mobility system in functional urban areas and the improvement of road safety. In addition, suburbanisation and dispersed buildings are considered to be severe barriers to maintaining and developing public transport services. As a consequence, heavy reliance on passenger cars continues and is supported by low-cost parking in cities. Although many cities introduced paid parking zones, traffic calming and limiting the supply of parking spaces in selected parts of cities to expand the space for pedestrian and bicycle traffic, the scope of such activities largely depends on the determination of local government authorities. Ultimately, this leads to increased greenhouse gas and particulate emissions, more accidents, and time lost due to congestion (Ministry of Development Funds and Regional Policy, 2022).

Other challenges for public transport are lack of sufficient financing and difficulties in integrating urban (municipal) and regional transport. The gradual development of rail transport to service agglomerations and semi-rural areas is hampered by numerous barriers, including low-quality railway infrastructure, rolling stock shortages, and increasing financing costs for current operations, particularly with increasing energy prices in the background. These challenges are worsened by lack of tariff integration and weak or non-existent cooperation of local governments at various levels.

Considering solutions to the identified issues, KPM2030 emphasises the importance of solutions related to cycling, walking and micro-mobility in the development of urban mobility. However, pedestrians and cyclists remain the least protected road users. In combination with increasing active mobility, the document indicates the need to encourage behavioural changes and reduce car use.

In this context, however, the current crisis also opens new opportunities to rethink urban mobility. Improving its functioning requires the simultaneous undertaking of multidimensional actions at multiple levels of government. This should include removing legal barriers to further integrate the public transport system and implementing the technological upgrades needed to do so including further digitalisation of mobility services. Additionally, measures supporting pedestrians and cyclists in cities and reducing car traffic should be adopted (Ministry of Development Funds and Regional Policy, 2022).

Transport-related strategic documents

National Transport Policy 2006-2025

The “National Transport Policy 2006-2025”, introduced in 2005, codifies the principles of sustainable development as the primary goal of Polish transportation policy (Ministry of Transport Strategy, 2005). The document identifies multiple aspects related to transport demand, such as land use, individual consumption patterns, automotive policy, and fiscal measures. As a framework document, it guides future regulations and planning through critical methodologies and principles. It emphasises the importance of long-term action plans and strategies, dissemination of the most cutting-edge information

available, and supporting innovative solutions at all levels of government when developing transport and environmental policies. The framework emphasises the need to increase competition in the transport sector beyond air and road, maximising environmental considerations when creating new projects, including the total cost of environmental degradation and emissions in decision-making, and removing industry subsidies promoting environmental harm.

The following aspects were indicated as particularly important for limiting the negative impact of the transport system on the environment:

- Introducing the principle of improving and developing the transport system by implementing long-term plans and action strategies.
- Increasing the competitiveness of modes of transport other than road and air transport.
- Supporting the idea of including external costs and eliminating environmentally harmful subsidies in decision-making.
- Considering environmental protection aspects, especially nature protection, in the design and construction of transport infrastructure, to the maximum possible extent.
- Introducing the obligation to formulate transport policy (as resolutions) at various levels of local government structures, considering the principle of balancing the transport system.
- Promoting solutions in spatial and functional integration of transport subsystems.
- Disseminating the best solutions and knowledge and promoting innovative solutions in the field of the transport system.

Act on electromobility and alternative fuels

The Act comprehensively describes the principles of operation of the electromobility and alternative fuels sector in Poland, setting the framework for developing this sector for the future (Ministry of Energy, 2018). The Act stipulates rules for the development and operation of infrastructure for the use of alternative fuels, including the technical requirements to be met by this infrastructure. Additionally, it outlines obligations of public entities in the development of alternative fuels infrastructure and information obligations regarding alternative fuels. The act also outlines implementation of clean transport zones (in other words, a low emission zone; LEZ) and conditions under which certain vehicles and alternative fuels could enter these zones (Ministry of Energy, 2018).

Transport Sustainable Development Strategy until 2030 (2019)

As of June 2023, the document setting out the most important guidelines for transport development in Poland was the "Strategy for Sustainable Development of Transport until 2030", introduced in 2019. The main objective of the Strategy was "increasing the transport accessibility of the country and improving the safety of traffic participants and the efficiency of the transport sector by creating a coherent, sustainable, innovative and

user-friendly transport system at the national, European and global level” (Ministry of Infrastructure, 2019).

To achieve this objective, the Strategy envisages construction of an integrated and interconnected transport network serving a competitive economy with improved organisation and management of the transport system. Public funds for transport projects would be more efficiently used, and funded projects would have reduced environmental impact. Individual and collective mobility would shift, with increased road safety and promotion of public transport pushing people towards utilisation of public and active modes of transport.

National Road Safety Programme

Published by the Ministry for Innovation and Transport in 2020, the National Road Safety Programme seeks to reduce the number of severe injuries and road fatalities in Poland (OECD ITF, 2022). By 2030, the programme targets reducing the number of fatalities by 50%, or to no more than 1,455, and reducing the number of severe injuries by 50%, or to no more than 5,317.

To achieve this, the programme introduces five pillars of action:

- I. Road safety management systems
- II. Safe users
- III. Safe roads
- IV. Safe vehicles
- V. Rescue and post-accident care (Ministry of Infrastructure & Secretariat of the National Road Safety Council, 2020).

Energy-related documents

Poland's energy policy until 2040

Poland's energy policy until 2040 (PEP2040) sets the framework for energy transformation in Poland. It is one of the nine integrated sectoral strategies resulting from the Strategy for Responsible Development. The specific objectives of PEP2040 cover the entire energy supply chain - from obtaining raw materials, through the generation and supply of energy (transmission and distribution), to how it is used and sold. A low-emission energy transformation will be carried out by implementing the objectives and activities indicated in PEP2040. One of the three pillars of the Strategy is "good air quality", which includes electrification of transport (Ministry of Climate and Environment, 2021a). The document includes pursuing zero-emission public transport by 2030 in cities with more than 100,000 inhabitants.

National Energy and Climate Plan for 2021-2030

The National Energy and Climate Plan (NECP) presents national assumptions and targets, as well as policies and actions regarding the Energy Union's five dimensions,

including decarbonisation. The document contains activities to support the development of electromobility and the construction of alternative fuel infrastructure (Ministry of Climate and Environment, 2021b). One of the document's objectives is to achieve a 14% share of renewable energy sources in transport. The Plan provides, among other things, support for further electrification of public collective transport. The plan includes a provision on supporting low-emission public transport in cities from the EU Cohesion Fund through continuation under the Operational Program Infrastructure and Environment in the period 2021-2027. By 2030, this funding is projected to help increase the fleet of electric buses to 3,000 vehicles.

In the transport sector, the NECP aims to reduce the negative impact of transport on the environment in alignment with the Strategy for Sustainable Development of Transport until 2030. The key target is reduction of average CO₂ emissions from the fleet of new passenger cars and light vehicles by 37.5% by 2030 (Ministry of Climate and Environment, 2021b). Additional targets include increasing the number of alternative fuel vehicles to 54,000 compressed natural gas (CNG) powered vehicles and 3,000 liquified natural gas (LNG) powered vehicles by 2030 (Ibid.).

Within the category of research, innovation, and competitiveness, the NECP presents overarching goals of increasing Polish competitiveness in the energy market and improving the quality of life of its citizens. Specifically, Poland plans to pursue an increase in spending on research and development, from 1.7% of the GDP in 2020 to 2.5% of the GDP in 2030 (Republic of Poland, 2019b). Included in this spending is an interest in investing in research efforts on autonomous vehicles and the potential for increased efficiency and greater support for EV battery recycling, citing the increasing number of EVs on the roads and subsequent need for recycling capabilities in the short and medium terms.

Polish Hydrogen Strategy (2021)

Hydrogen as an alternative fuel in transport has been recognised as one of the six goals of implementing and developing hydrogen technologies (Council of Ministers of the Republic of Poland & Ministry of Climate and Environment, 2021). The Hydrogen Strategy projects annual hydrogen consumption in the transport sector at 32,000 tonnes in 2030.

Significant actions in this area were projected, including deployment of between 100-250 new hydrogen buses by 2025, and introduction of hydrogen trains to replace old diesel engines on routes that aren't suited to electrification. Other projected measures include construction of at least 32 hydrogen refuelling and bunkering stations, construction of installations for purifying hydrogen, starting design work on the first ships with a hydrogen-based propulsion system, and launching pilot programs for the use of hydrogen and its derivatives in public transport, heavy road, rail, sea, river and air transport as well as intermodal transport (Ibid.).

Polish modal split and passenger transport emissions

The total passenger activity in Poland has been rising steadily over the past two decades from 236 billion passenger kilometres (pkm) in 2000 to 362 billion pkm in 2021 – an increase of 55%.¹ During the same time, total emissions from the passenger transport sector increased by 94%: from 22 MtCO₂ in 2000 to 42.2 MtCO₂ in 2021. In 2021, the average citizen emitted over 1044 kgCO₂ from passenger transport. The much faster increase in emissions compared to mobility indicates an increase in emissions intensity per passenger-kilometre travelled: from 92 to 116 gCO₂ during this period.

Passenger cars account for over 80% of the modal split in Poland as of 2021- an increase from 74% in 2000. At the same time, passenger cars saw significant fall in occupancy rates, which decreased from 1.52 persons/vehicle in 2000 to 1.20 persons/vehicle in 2021. Personal vehicles account for the largest share of passenger transport emissions in Poland; in 2021, over 80% of passenger transport emissions per capita were produced by cars. Passenger cars emissions intensity decreased slightly between 2000 and 2021 from 187 gCO₂/vkm in 2000 to 170 gCO₂/vkm in 2021.

Poland modal split 2000 (left) and 2021 (right)

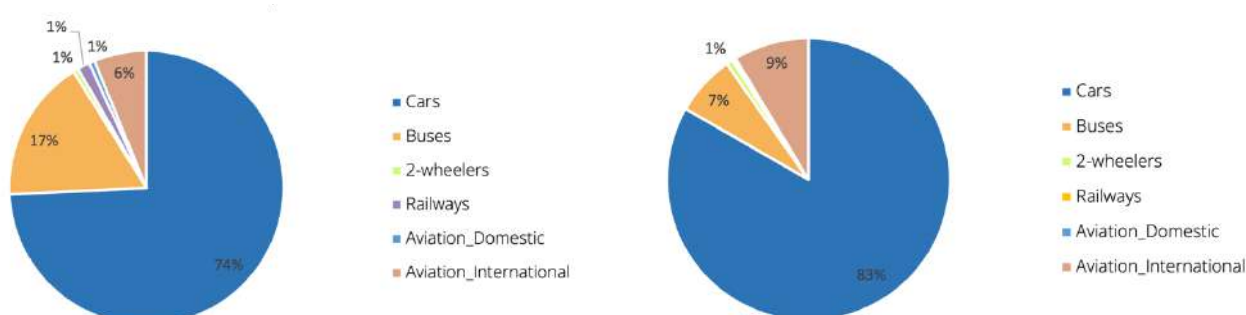


Figure 1 Poland modal split

Activity levels for motorcycles have almost quadrupled between 2000 and 2021, with the greatest increase between 2009 and 2010. As a result, their share in activity increased from 0.5% to 0.75%. However, data for this mode of transport varies significantly between sources.

Before 2018, when they were exceeded by aviation, buses constituted the second major contribution to mobility in Poland. However, an increase in overall mobility - mostly by highly carbon intensive modes of transport – contributed to the steady decline in bus

¹ The data provided in this section have been calculated using Transport Emissions Disaggregation Tool (TEDiT). Climate Analytics (2023). Transport Emissions Disaggregation Tool. Retrieved from <http://tools.climateanalytics.org/tedit/>

utilisation. Between 2000 and 2021, the load-factor of buses decreased from 30 to 10 pkm/vkm. This decline was to some degree counterbalanced by a decrease in emissions intensity, which fell from 1,890 gCO₂/vkm to 1,441 gCO₂/vkm in the same period. As a result, their share in overall emissions from the passenger transport declined from roughly 17% to 7%.

With 416 pkm/capita in 2021, the average activity from railways in 2021 was nearly 30% below the activity in 2000, which was 630 pkm/capita. The contribution of railways to overall emissions in the passenger transport sector decreased much faster than their contribution to activity levels. Whereas railways were responsible for 1.4% of overall emissions from passenger transport in 2000, by 2021 their share fell to 0.2%. By the same token, railways have observed the steepest decline in emissions intensity from 1,829 gCO₂/vkm to 499 gCO₂/vkm over the past two decades.

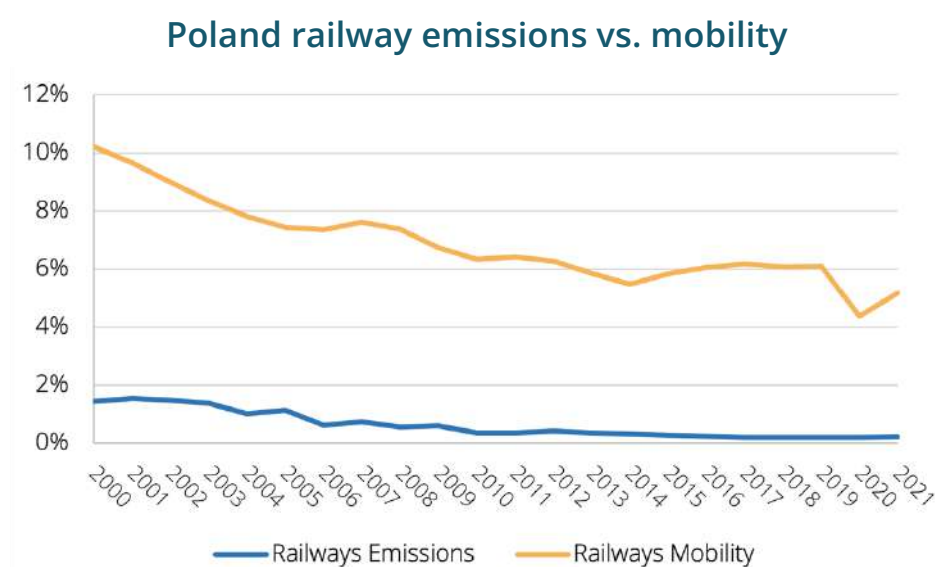


Figure 2 Railways emissions and mobility (as % of total)

For subways and trams, the activity levels remained relatively stable, decreasing slightly from 123 pkm/capita in 2000 to 115 pkm/capita in 2021, a 6% drop. Since emissions from electricity generation are not included in the assessment, there were no emissions from this mode of transport.

Between 2000 and 2010, the average citizen travelled 9 km per year by plane on domestic routes. In the following decade this number doubled reaching a high of 20 km per year per capita in 2017, however by 2021 this decreased to 7 pkm per capita, probably driven to a large degree by the COVID-19 pandemic, as well as increasing popularity of railways. While in 2021 domestic aviation contributed less than 0.1% of mobility, due to the highest levels of emissions intensity, its share in emissions was more than twice as high.

The distance travelled by international planes increased from 102 pkm per capita in 2000 to 406 pkm per capita in 2021. However, due to the pandemic-related limitations in travels, this was significantly lower than the 2019 high of 1040 pkm per capita. Since

2018, international aviation has become the second largest contributor to mobility, second only to passenger cars. Despite an increase in overall mobility, the share of aviation has more than doubled: from 6% in 2000 to 14% in 2019, once again falling between 2020 and 2021 due to pandemic restrictions on travel. Contrary to international trends, emissions intensity from this mode of transport increased slightly, from 29,800 gCO₂/vkm to 31,720 gCO₂/vkm. The share of emissions from this mode of transport was much higher than the contribution to mobility.

While there are no data for cycling and walking in Poland, we assume an average distance of around 100 km cycled and twice as much walked per person. This is based on the average available for Hungary at around 84 km per capita and between 85 and 491 km for Denmark, the Netherlands, and the UK.

Main drivers of emissions from passenger transport

Passenger transport emissions are influenced by a number of different interacting factors. Income growth has been and continues to be the main driver of passenger transport emissions. Higher incomes make cars more affordable, encourage mobility, and allow people to move to the suburbs, making the private car irreplaceable in most cases. In Poland, according to preliminary estimates from the Central Statistical Office, GDP in Q1 2022 grew by 8.5% year-on-year, compared to 7.6% year-on-year growth in Q4 2021. On a quarter-on-quarter basis, GDP grew by 2.4% in Q1 (Staff, Prawna Gazeta, 2022).

As of 2021, there were more than 25 million passenger cars registered in Poland, which is 3.1% more than a year earlier. There are 656 cars per thousand inhabitants in Poland, up from 539 in 2015, and double the 2005 level (Wojtkiewicz, 2021). The data also says that more than 16% of cars are more than 30 years old (and 11% are less than 5 years old) and that consumers are buying cars that are getting heavier (a 30% increase in vehicles weighing more than 1,900 kg). In essence, the Polish car fleet has exploded, and is comprised of primarily older, heavier cars all of which contribute to increased emissions levels.

The number of EVs on the road continues to grow. As of June 2023, over 80,000 passenger and commercial EVs were registered in Poland. In the first six months of the year, their number increased by 17,314 units, or 11% more than in the same period of 2022 (PZPM, 2023). The impact of an EV in Poland is slightly different than elsewhere in Europe, due primarily to the energy mix used to power the car. Transport & Environment estimated that an electric car on Swedish roads emits 79% less greenhouse gases than the average petrol or diesel car with an internal combustion engine (ICE). The same car used in Belgium emits 65% less, in Germany 56% less and in Poland only 29% less (Wojtkiewicz, 2021). While emissions from production of the EV is the same for all countries, the differences in emissions level depend on how the electricity needed to power the battery is produced. The cleaner the energy mix, the lower the emissions of an electric car. It is therefore clear that the transformation of the national electricity mix is of key importance for the effectiveness of electromobility development in Poland.

The process of decarbonisation of transport in Poland through the use of fuels and energy from renewable sources is developing very slowly and new technologies are not competitive with the cheapest solutions, which are biofuels from crops. So far, the dominant bio-component in Poland is biodiesel, followed by bioethanol. In 2018, they accounted for about 80% of renewable energy sources (RES) in transport (Motowidlak, 2020).

The development of low-carbon transport is essential to Poland's efforts to improve urban air quality and achieve climate neutrality. Based on the current reliance on passenger cars and their heavy carbon footprint, a systemic approach to decarbonisation of the transport sector is required. Moreover, the sector needs to adapt to the projected growth in passenger and freight mobility needs.

To achieve the 2030 climate policy and climate-neutral economy targets, Poland must promote the development of multimodality using rail transport, combining different modes of transport efficiently and further developing electromobility. Considering the demand for passenger and freight transport, changing attitudes towards mobility, and the current level of development of Polish transport, these solutions are realistic and achievable (Motowidlak, 2020).

While there is an evolution in the field of mobility, to achieve national climate commitments a revolution is needed. Key actions include intensive development of railways, electrification of passenger cars and urban transport, and increasing infrastructural support for other forms of active mobility, such as cycling and walking (Wojtkiewicz, 2021).

Availability of Used Cars

Fuel consumption in transport sector in Poland has significantly increased since 2005. Notably, consumption increased by 37% between 2016 and 2017 in the road transport sector alone (IEA, 2022; Poland Statistical Office, 2022). Because of the large amount of second-hand vehicles in Poland, emissions increased by over 83% between 2005 and 2021, increasing the transport sector's share of total emissions to 20.7% in 2021 (Climate Analytics, 2023). There is, however, large potential for emissions reductions due to technical developments and the potential for an increase in energy efficiency of privately owned cars. Reducing car-related pollution would lead to reduced pollution in urban centres, and could incentivise transitioning to EVs. While complete decarbonisation resulting from the EV transition is difficult to reach because 80% of Poland's electricity is derived from fossil fuels (IEA, 2022), EVs are immediately responsive to any positive changes in the way electricity is generated.

Good Practices

This section describes some good practices affecting different modes of transport that could increase the utilisation rate of the low emissions modes of transport, especially cycling, railways, and public transport, expecting modal shift from highly emitting means of transport such as aviation and passenger cars. The practices also include overarching measures, that would further promote such shift by development of city of short distances. Furthermore, electrification of buses (especially by combination of trolleybuses with batteries) could reduce emissions intensity of mode of transport. Integrating ticketing between railways and other modes of public transport could increase intramodality and facilitate shift from passenger cars to cleaner modes of transport.

City of short distances

A city of short distances is an urban concept that promotes a relatively high density of built-up land together with a mixed land use. An efficient public transport system should encourage people not to use cars, instead encouraging walking and cycling (Węclawowicz-Bilska, 2012) as well public transport. Such a system can contribute to low energy consumption and low environmental pollution. The large number of inhabitants provides opportunities for social interaction as well as a sense of security. The Compact City (city of short distances, 15-minute city) concept has had a particularly strong influence on urban planning policy in the UK between 1997 and 2010 and has mainly concerned regeneration areas.

A city of short distances, also known as a 15-minute city, can alleviate many of the problems plaguing cities today and introduce zero carbon transportation, leading to significant emissions reductions. Spatial chaos, suburbanization, social fragmentation and increasing distances between origin and destination make a car a “natural” choice for many journeys. Additionally, providing efficient and accessible public transport services means high budgetary expenditures – often a challenging ask in times of crisis, inflation, and overall instability. The strong market position of a car results in increased emissions, congestion, and decreased traffic safety. Increased demand for parking spaces means losing an alternative to other use of space in dense urban areas.

The concept of cities of short distances is a long-term urban planning effort aimed at increasing the accessibility of the different functions located in the city space to ensure convenient access for all social groups, regardless of their age and socio-economic status. The city of short distances is a set of comprehensive measures, the diversity of which determines its versatility and the possibility of implementation anywhere. Short-distance city measures address problems including traffic safety, accessibility of schools, and the lack of green and recreational areas. With a comprehensive approach, the city of short distances also addresses the problems of spatial chaos, excessive car use, and low physical activity levels of residents.

Vienna – a good example

According to its recent urban development concept, the Austrian capital city of Vienna is to become a city of short distances (Eurocomm-PR, 2020). This means that majority of amenities and facilities necessary for everyday life will be available to residents in 15 minutes. One of the targets is for at least 70% of all journeys in Vienna to be short-distance, up to 5 km, by 2030, and thus could be by bicycle or on foot. Moreover, “a city of short distances and lively neighbourhoods” is a part of Vienna’s 2050 vision.

To make such an ambitious goal feasible, urban policy has been directed towards providing basic social infrastructure (schools, health care, shopping and leisure facilities, parks etc.) in relatively close proximity to places of residence. Reallocation of street space towards active modes of transport and an increase in the importance and accessibility of all forms of transport alternatives to the private car further support this measure.

The priority on the path to city of short distances is to provide and offer local infrastructure opportunities to inhabitants to minimise the number of unnecessary daily car trips. Efficient and reliable transport systems are essential and must enable people to switch easily between different modes of transport. The pandemic and the accompanying lockdowns have highlighted the role of mixed-use and easy access to essential public services in a situation of restrictions on collective modes of transport. Also, the energy crisis and the resulting increase in the price of electricity and liquid fuels are prompting a review of urban planning, prioritising accessibility of local neighbourhoods by the cheapest and lowest energy means of transport - walking and cycling. This approach additionally improves social cohesion, counteracting social and economic atomisation.

Implementation

There are two main challenges commonly brought up when discussing the pedestrian-only spaces that a city of short distances is built around. First, some inhabitants of the pedestrian-only zones may still need to use cars for various reasons. Second, businesses whose customers may need to rely on car transport may be negatively affected. Both challenges can be mitigated by allowing for very limited car travels, e.g., only one lane and significantly reduced speed. Provisions should be made for zone inhabitants who own personal vehicles, including off-street or underground parking to maximise the utilisation of the space freed by the parking spaces for other purposes. Businesses should allow for parking for only a limited time and certain shops offering products that can only be transported by car could offer delivery, especially if tax subsidies are offered for affected businesses. In this case, the respective company cars could be allowed into the pedestrian space during business hours. Implementing pedestrian-only spaces requires long-term planning, preferably implemented at the stage of urban or district planning.

Polish cities have been developing standards for shaping pedestrian space for a decade. They are the basis for investment and renovation activities of various scales and levels of intervention in the existing urban area. For example, the “Wrocław Pedestrian-Friendly Urban Spaces Design Standards” are a comprehensive guide that includes a set of guidelines for planning, designing, and implementing pedestrian infrastructure. In Warsaw, a policy limiting car traffic in certain zones, emphasizing public transport, cycling, and pedestrian traffic was introduced (PTC Public Transport Consulting, 2017).

Zielona Góra – the city of short distances in the Sustainable Urban Mobility Plan

Zielona Góra (141,000 inhabitants) is characterised by a very high share of pedestrian travel due to its spatial structure and existing pedestrian traffic zone. At roughly 31% of the modal split, the increase in the share of pedestrian trips creates demand for diverse and accessible space and supports implementation of the city's Sustainable Urban Mobility Plan (SUMP) (City of Zielona Góra, 2022).

Through the SUMP, the city aims for the 8/80 concept, in which space should be friendly to both an 8-year-old child and an 80-year-old resident of Zielona Góra. Moreover, facilities for people with various degrees of motor and sensory disabilities also enable access for other users.

To meet transport and planning goals, actions planned in the 2017 SUMP targeted pedestrian traffic specifically. The Plan included improved lighting of selected crossings, reconstruction of crossings to improve traffic safety, creation and modernisation of intra-district pedestrian routes, the development of accessibility standards considering the needs of persons with reduced mobility, and comprehensive revitalisation projects for city parks and green areas. The need for lighting improvements were direct results of the discussions during workshops with citizens (Police Headquarters, Traffic Bureau, 2022).

The implementation of the city of short distances requires involving a number of important stakeholders, especially representing city authorities and residents. Changes, particularly regarding the new division of street space, should be implemented through ongoing dialogue with residents. Other important stakeholders could include developers, housing cooperatives, directors of kindergartens and schools, and representatives of NGOs that are active in each area. Local businesses should be included in discussion, with opportunity for interesting proposals and ideas to come from the private sector.

Stakeholder identification and engagement has begun in several Polish cities as local governments want to implement the idea of a city of short distances when carrying out public investments (Rzeczpospolita, 2021). "Around the City in 8 Questions" was a series of virtual meetings with mayors of the largest Polish cities and served to present the strategy and spatial policy, vision and mission of city development. As a result, it enabled an open dialogue between city mayors and representatives of the real estate industry (AKL, 2021).

One of the cities participating in the virtual meetings from the series is Poznań. The city implemented investments worth PLN 1.2bn (roughly EUR 268 million) (Rzeczpospolita, 2021). Apart from "large-scale" undertakings, the city authorities focused also on developing a city of short distances, with its own local service centres catering for everyday needs and jobs for its inhabitants. The ambition was to develop an urban space that can be used on one's own feet, which is in line with the assumption of the 15-minute city. The SUMP for Poznań, adopted in 2021, appropriately balances infrastructure and rolling stock development with so-called 'soft measures' to increase the quality of life and improve access to local services.

The city of Gdańsk likewise aspires to become a city of short distances. The metropolitan railway is the backbone of the whole agglomeration's system, but it needs appropriate additional infrastructure. In a SUMP for Gdansk (2018) an improvement of conditions for pedestrian and bicycle traffic, improvement of the public transport system and its integration with active forms of mobility was projected (City of Gdansk, 2018).

There are several infrastructural elements crucial to a short-distance city. For example, improving the orientation of pedestrians is growing in the context of the need to increase the safety of road traffic for the most vulnerable groups - pedestrians and cyclists as well as people with disabilities, particularly sensory disabilities. Currently, many cities in Poland have introduced pedestrian infrastructure design standards. The pedestrian standards developed in the city of Lublin in 2016 (City of Lublin et al., 2016) distinguish three levels (scales) of detail in the design of space from a pedestrian perspective, namely:

- **Planning scale** - at this level, apart from the apparent provision of pedestrian priority and continuity of the pedestrian route system, it is postulated that the legibility of the spatial structure should be ensured. This involves "ensuring good orientation for pedestrians by avoiding complex or monotonous spatial structures (e.g. grid streets in single-family residential neighbourhoods). Structures based on a clear grid of varied streets in which directions can be easily distinguished and pedestrians can clearly identify the routes to their destinations are considered to be appropriate."
- **Street scale** - at this level, it is recommended to apply universal design principles that assist people with disabilities in moving around.
- **Detail scale** - this level recommends "the systematic removal of excessive traffic signs and duplicate messages" to improve the perception of signs by road users, reduce the number of obstacles on pedestrian routes, and improve the aesthetics of the space and reduce spatial chaos.

Proposed changes to the existing legislation

The process of city transformation in line with the idea of a city of short distances requires many years of planning and significant organisational, management and investment efforts. The scale depends on the size of the city, its functional and spatial

structure, the priorities set, and the resources available. However, it is possible to focus on a specific part of the urban space in such a way that it later becomes an incentive for inhabitants in other parts of the city.

From the Polish perspective, it is necessary to strengthen local authorities' tax base to make them more independent from external funding sources to transform urban space. In addition, the suburbanisation processes that Polish cities have been experiencing for almost 30 years have not received a proper response in the Polish legal system. Spatial planning is the domain of local authorities, while the solutions and resources needed at the metropolitan level are lacking.

Co-benefits

The benefits of implementing the short-distance city concept are immense and go well beyond climate change mitigation. In the long run, the concept contributes to more environmentally friendly and healthy transport choices, reducing the need for private cars. This effect will be enhanced when other measures are included, e.g., promotion and education of active forms of mobility, restrictions on vehicle parking, infrastructural interventions improving road safety, and development of safe cycling and walking infrastructure. Improved air quality, increased physical activity, greater traffic safety, and a more coherent urban fabric are all co-benefits of implementing the city of short distances concept (Otodom Analytics, 2022).

All the above positive factors contribute to the regeneration of urban vitality, an overall higher quality of life, and the creation of favourable conditions for increased economic and commercial activity. In other words, conditions are created for sustainable development, based on combined economic, social and environmental elements, bringing the urban area closer to the idea of the compact city. From a budgetary perspective, a city of short distances can encourage more efficient use of financial resources for provision of local public services.

Conclusions

The concept of a city of short distances is even more important following the recent crises; space that is too transport-intensive is more vulnerable to shocks from pandemics or energy crises. Active mobility and sensible space management allow local communities to function relatively undisturbed in the face of significant external pressure.

Creating more pedestrian-only zones is a gradual process whereby city authorities must consider conflicts resulting from the use of urban space. The city centre is often the most valued space and is treated as a common area for all citizens, making it the ideal place to begin to implement planning changes. Polish cities are implementing a variety of measures enabling pedestrianisation and enhancing walkability. Many of them are supported by guidelines and technical standards, which consist of technical norms and solutions and treat urban space more horizontally, providing support for urban

greenery, urban design, multiple forms of active mobility. The perception of safety and connectivity are the most influential factors in developing a walkable environment. Therefore, investment in lightning and its improvement is an important element supporting a walkable city.

Developing cycling infrastructure

For many years cycling in Poland was treated as an element of recreation. Only gradually that view has changed. In strategic documents of Polish towns and cities, cycling is acknowledged as a fully-fledged means of transport, whose advantages have not been fully exploited so far. To give cycling infrastructure an added value for a city's transport system, its development should include promotional and educational measures and consider the cycling network and public transport development of neighbouring towns and cities. Additionally, in terms of spatial planning, the importance of cycling should grow.

One of the first stages of implementing sustainable mobility solutions in Polish cities was the construction of cycling infrastructure. In many cities, this task is positioned as a critical task. At present, the activities of cities focus on complementing the network, changes in traffic organisation, creating convenient transfer nodes, and binding the network of the city and its functional area.

In Poland, there is a diversified level of cycling infrastructure development. According to the Polish Central Statistical Office, the total length of bike routes in Poland in 2021 reached over 18.5 thousand km, an increase of 3,000 km compared to 2019. In several cities, the share of cycling has risen significantly over the last few years. In 2022, 79% of households in Poland owned at least one bicycle, an increase of 7% compared to the 2016 results (CentrumRowerowe, 2022). The development of cycling infrastructure and the creation of solutions supporting cycling traffic has been systematically improving for years. However, the scale of activities varies in cities. For instance, the highest density of bicycle roads is in small and medium-sized towns which have the greatest potential to make most of commuting by bike (Gadziński & Goras, 2019).

The COVID-19 pandemic has radically affected the functioning of urban transport systems. Restrictions have concerned public transport both on the demand side (teleworking, distant learning) and supply side. This has translated into a widening gap between ticket sales revenue and the cost of operating public transport. As a consequence, subsidies from city budgets to public transport have increased. In 2023, a gradual trend of rebuilding the demand for collective transport is observed, but with much higher costs (inflation, wage expectations and costs of fuel and electricity). Cycling is however a transport subsystem resistant to lockdown and costs mentioned above. Thus investing in the development of cycling in cities is a highly effective action to combat operational challenges presented by health or other crises.

Implementation

Poland's accession to the European Union enabled Polish cities to access additional funds to develop neglected infrastructure areas. Among these areas was cycling infrastructure, and development has been visible in recent years. Moreover, the development of cycling infrastructure and the aim to increase the share of cycling in the modal split is one of the most important elements of sustainable mobility plans, thus giving it access to further sources of funding targeting climate change mitigation.

Cycling as an important element of the sustainable urban mobility planning: Poznań

In Poznań, one of the biggest Polish cities, the connectedness of the cycling route network has been identified as the most crucial driver increasing the role of cycling in modal split. The urban space of Poznań will require the construction of several additional cycle track crossings over barriers like the Warta River, expressways and railway tracks. Great importance is also attached to integrating the improvement of cycling network into main routes and complementary network (City of Poznan, 2022).

For Poznań, an increase in the role of cycling will result from the following categories of measures: implementation and evaluation of the Cycling Programme, reduction of spatial barriers in pedestrian and cycling traffic, separation of pedestrian traffic from cycling, elimination of architectural barriers in pedestrian and cycling traffic, creation of a cyclist counting system, introduction of a municipal discount scheme for cycling commuters, and development of the Poznań Urban Cycling System (City of Poznan, 2021). The length of cycling routes (243 km in 2018, target value in 2030 – about 330 km) and the volume of Poznań Urban Bicycle rentals are two indicators to measure the role of cycling in mobility.

A significant increase in cycling infrastructure took place in Warsaw, where the length of cycling routes nearly doubled between 2013 and 2021. The capital city also has the most developed cycling infrastructure in the country, with over 700 kilometres in 2021. Warsaw has focused on the development of bicycle paths due to increasing bicycle traffic – in 2020, the increase in cycling traffic amounted to 17.4% (Zarząd Dróg Miejskich w Warszawie & SIMRUN, 2021). However, the results of research conducted in 2021 showed a decrease in the number of bicycle trips by 8.9% compared to 2020, although these data should be treated with caution due to the pandemic situation (Góralski et al., 2021).

Apart from the direct development of cycling infrastructure, there are many other measures that increase the efficiency of cycling solutions, including improvements in the safety of cycling, soft measures such as promotion campaigns, as well as introducing bike-sharing and cargo-bikes.

Wrocław – one of the leading cycling cities in Poland

One of the cities that has consistently focused on the development of bicycle transport is Wrocław. A survey conducted in 2018 showed that three-quarters of the inhabitants use the cycle paths in Wrocław. Moreover, the average number of bicycles per household increased from 1 in 2011 to 1.2 in 2018, with an estimated 30,000 bicycles in use every day across the city. The share of cyclists in urban travel rose from 4% in 2011 to 6% in 2018, a good result for Poland. Length of cycling lanes in Wrocław increased from 198 km in 2011 to 360 km in 2020 and infrastructure including cycling-friendly streets, trails in parks, etc. amounted to 1100 km (City of Wrocław, 2018). A radical change in traffic organisation accompanies the development of dedicated cycling infrastructure. Furthermore, in a large part of the city, speed limit for cars at 30 km/h has been introduced, which creates favourable conditions for the development of cycling and improves traffic safety.

Improvement of cycling safety measures

Improving cycling safety remains a priority in Poland, though accidents have decreased in recent years. In 2021, cyclists were involved in roughly 3,500 road accidents in which 185 cyclists were killed and nearly 3,200 people were injured. Compared to the previous year, there were 255 fewer accidents involving cyclists (-6.8%). Moreover, in 2020 compared to 2019, the number of accidents involving cyclists decreased by almost 15% (Police Headquarters, Traffic Bureau, 2022). However, part of this decrease could have been caused by COVID-19 related reduction in car traffic.

Poland has already implemented some efficient solutions that increase the safety and comfort of cyclists. Separators are one of the most popular elements of the infrastructure, clearly dividing pedestrian pavement from the bicycle path, and have been implemented in most Polish cities (Rowerowa Łódź, 2022). This both improves the safety of road users and reduces the risk of conflicts between cyclists and pedestrians. Other popular solutions for increasing cycling lanes' safety include designating speed limit for passenger cars at 30 km/h. Examples can be found in Gdańsk or Poznań. In addition, larger cities such as Warsaw have implemented bicycle paths which flow behind bus stops and decreasing potential conflict between cyclists and pedestrians.

There are also "Guidelines for safe bicycle traffic" – a design standard for bike lanes (Ministry of Infrastructure and Development, 2022). According to the guidelines, the bicycle path should be slightly elevated in relation to the road to increase separation between cyclists and cars. Additionally, new cycling paths should have lane markings that are distinguishable from other road markings, e.g., coloured intersection crossing markings which are widely spread in many major Polish cities such as Warsaw and Wrocław.

To facilitate uptake in cycling, other cycling-related infrastructure should also be developed. Some cities have implemented structures at crossings to lean on while waiting at a crosswalk, and to support those with mobility concerns (Rowerowa Łódź,

2022). Supports are also used as road safety elements, segregating pedestrian and bicycle traffic. Wrocław and Warsaw were the first cities to implement this solution.

Under the project “Cycling Downtown Gdansk”, cyclists have been allowed to use both directions on all one-way streets in the Main and Old City and the maximum speed of vehicles is limited to 30 km/h on all roads in the historic centre of Gdansk. Moreover, zones of parallel intersections were introduced, which enforces a greater vigilance of drivers and limits “blind” driving cases. Initially, the project generated significant reactions – from admiration for low-cost solutions improving the accessibility of transport and safety of cyclists and pedestrians to concerns about the increase in the number of accidents and fatalities. Despite concerns brought up by some community members, the introduced solutions fully met their role relatively quickly, and the city received requests from other districts to implement similar solutions. Currently, 62% of the road system in Gdańsk is covered by the Tempo 30 Zone (City of Gdansk, 2018). Additionally, the action plan of Sustainable Urban Mobility Plan (SUMP) of Gdańsk includes replacement of pedestrian crossings in the form of bridges and tunnels with ground crossings and designation of missing pedestrian crossings on main traffic routes and near interchanges (Ibid.).

‘Soft measures’ supporting cycling infrastructure development

Though important, the construction of cycling infrastructure constitutes only part of comprehensive measures aimed at increasing the share of cycling in traffic. Campaigns promoting cycling transport, addressed to various social groups, e.g., children and their parents, are also key to shifting mobility preferences.

“Cycling May” campaign

In 2014, the City of Gdansk launched Poland’s first “Cycling May” campaign, a campaign that has since spread across the country and become the most extensive campaign in Poland promoting healthy lifestyles and sustainable mobility among preschool children, primary school pupils and teachers (City of Gdansk, 2022b). Invitations from local authorities or delegated organisations are addressed to all departments of a given institution, encompassing children aged 3 to 15 and all staff.

The campaign provides an opportunity to merge different educational activities focused on traffic safety. For instance, in the inaugural campaign in 2014, through brochures designed for parents, organisers sought to ensure that parents perceived cycling as a safe and healthy commuting option. As a result, pupils and parents were soundly prepared and motivated to actively participate in “Cycling May.”

In 2022, schools and kindergartens from 46 Polish cities participated in the campaign. Despite the pandemic, in Gdansk as many as 37 thousand participants from 190 institutions fought for the title of the best school, class, and kindergarten in “Cycling May 2022”. The share of pupils actively travelling to primary school or kindergarten by bike or in Gdansk amounted to 50% (City of Gdansk, 2022a).

In 2022, the City of Gdynia decided to support residents in purchasing electric bicycles, with the goal of promoting their usage and assessing the scale of potential demand. Interest exceeded all expectations. The plan initially allocated funding for 40 people to purchase electric bicycles, but over 1,300 people signed up for support and 120 e-bikes were granted in total. The campaign confirmed the desirability of electric bike subsidies and was closely watched by other cities. Recently, similar measure was being discussed in the city of Włocławek, with around 100,000 residents.

Bike-sharing

By reducing barriers to bicycle use and addressing the last mile problems, bike-sharing programs provide an alternative to private car use, thus resulting in lower emissions and increased mobility of citizens and visitors.

Currently, there are several city bike rental systems in Poland. The first was BikeOne in Krakow (implemented in 2008) and another was RowerRes in Rzeszów (launched in 2011) (wRower, 2022a). In Wrocław, NextBike opened its system in 2011, expanding to Warsaw, Opole and Poznań in 2012. In 2017, city bike systems were available in 28 cities and were operated by three operators: Nextbike (21 systems), BikeU (5 systems) and Romet Rental Systems (2 systems) (Gadziński & Goras, 2019). In Białystok and Lublin, the bike rental systems cover not only the city area, but also surrounding municipalities.

In total, Polish bike rental systems have had over a million users and 14 thousand bikes that have been rented at least 20 million times. The largest system is the Warsaw "Veturilo" with more than 330 stations, nearly 5000 bicycles and half a million users registered since 2012. On average, cycling systems in cities cover 500 bicycles operated by 46 stations. Warsaw and Lublin have had the highest bike station density, with over 60 stations per 100 km (Gadziński & Goras, 2019). However, the recent budgetary situation of self-governments has pushed several cities to stop operating the public bikes systems, including Poznań and Włocławek.

Cargo bikes

Although cargo bikes form a market niche in the dynamically developing cycling market in Poland, they present a potential in certain areas, including last-mile deliveries in dense, central urban areas. Therefore, they can be seen as an element of complex urban logistics solutions.

In July 2014, Warsaw made four cargo bikes available for rent. At the front, they have a box with a load capacity of 100 kg, which is also adapted to the transport of up to four children (wRower, 2022b). Gdynia has had cargo bikes available since 2018 (Polish Development Fund, 2022). The development of the cargo bike network in Gdynia was possible thanks to the support of the EU Interreg South Baltic and Horizon 2020 programmes. Residents of Gdynia (based on the Resident Card or the Library Card) can rent a cargo bike free of charge for up to seven calendar days and move around the entire Tri-City area.

In addition to standard cargo bicycles, cities also offer other solutions, such as tandems (in Białystok, Siemianowice Śląskie or Warsaw), children's bicycles (in Sosnowiec or Tychy) or bicycles with seats for children (available in Kołobrzeg) (Gadziński & Goras, 2019).

The City Council of Gdynia adopted a local council act on the principles of granting subsidies for the purchase of a cargo bike in 2018. It was the first grant of this kind in Poland. Individuals living in Gdynia, who will purchase a cargo bike could receive a refund of part of the cost up to 50% of the value of the purchased bike, or a maximum of PLN 5,000. This scheme has been co-financed by the European Union Horizon 2020 Framework Programme (City Council of Gdynia, 2020).

Stakeholders

The most significant potential in the development of cycling and its influence on daily mobility behaviour is revealed at the local level. Hence the key stakeholders are city authorities, NGOs (in practically every medium and large city, there is a pro-cycling organisation), shared mobility and micro-mobility operators. Less apparent stakeholders are transport authorities, as the bicycle plays an important role in the so-called "first/last urban mile" connecting users to the public transport network. In addition, the police, the municipal police, school principals, teachers, and parents are important recipients of measures aimed at improving road safety, particularly on the way to school. The school's surroundings should be an area of intensive investment and traffic reorganisation measures, prioritising active modes of transport. This also provides an opportunity to shape long-term educational efforts in the field of active mobility, in particular cycling. Mention should be made here of the successful campaign "Cycling May" (see the Box), in which hundreds of schools from various cities in Poland are involved.

The two most significant levels of implementation are local, at the municipality/city level and metropolitan/agglomeration level, at the level of urban functional areas. In the latter case, the integration of local cycling infrastructure networks is widespread in the development of SUMP and is one of the most frequently indicated courses of action.

Co-benefits

Cycling infrastructure is foundational for a city of short distances and provisions for cycling trips are a prerequisite for sustainable urban development. One of the most important co-benefits of cycling development is intermodality. To promote intermodality a growing number of Polish cities try to integrate cycling infrastructure with the public transport system by placing city bike stations and bicycle parking lots close to transportation hubs (Gadziński & Goras, 2019). City authorities, especially of big agglomerations, encourage the citizens of neighbouring municipalities to leave their cars at the borders of the city and use a different means of transport. Warsaw has had bike stands with electronic locks operated by Warsaw City Card at the transportation

hubs and Bike+Ride types of parking since 2015. In 2017, this idea was also introduced in Kraków.

Another concept linked to the development of cycling infrastructure is urban logistics. Part of the urban logistics solutions related to decarbonisation could be based on cargo bikes, forming “a green urban logistics” concept.

Conclusions

The development of cycling infrastructure is an important activity of the majority of Polish local governments. Although its pace varies from city to city, the general direction is positive. Infrastructure development is supported by a set of complimentary activities focussed on the education and promotion of cycling. Thanks to the growing number of railway and bus stops equipped with basic cycling infrastructure, last-mile options are enriched with cycling. Furthermore, it should be noted that bike-sharing schemes became a popular element of cycling development in many Polish cities. While it is unclear, to what extent bike-sharing is substitutional to public transport, as part of the overall transport network, cycling is critical.

Developing railway infrastructure

The development of rail transport is one of the critical areas of European Union transport policy. Railways represent an incredibly complex system, comprising the organisation of passenger transport, freight transport, and infrastructure management. The latter is essential for both categories of transport. It also determines the accessibility of regions and the possibility of integrating rail transport with other modes of transport.

Without an adequate volume of rail infrastructure (quantitative and qualitative), it will not be possible to change the modal split of journeys to a more sustainable one. Investments in railway systems are very expensive and require a long lead-time to pay back. Presenting railway development as an alternative to motorway development could increase public acceptance of this measure. In addition, the durability of the railway tracks (the tracks should be functional for decades with some maintenance) needs to be taken into consideration when the cost assessment is made.

Network capacity, or the highest number of trains (or pairs of trains) that can run across a section of railway line in a unit of time (Miecznikowski et al., 2021), is one of the critical factors affecting rail transport organisations. Capacity problems exist in the railway networks of most EU countries. One reason is the lack of separation between passenger and freight traffic. Also, for passenger rail operators carrying out transport in highly urbanised areas, a significant problem is the lack of capacity in the face of growing demand for transportation during morning and afternoon rush hours. Poor technical condition also impacts this issue. In Poland, over 4,600 kilometres of railway lines are affected by capacity problems (Urząd Transportu Kolejowego, 2021).

Over the last decade in Poland, the length of the railway lines in operation regularly decreased (Central Statistical Office of Poland (GUS), 2022). The majority of closures occurred in the 1990s and beginning of the 2000s. From 2017, it began to increase slightly, rising to 19,422 km in 2020 (Central Statistical Office of Poland (GUS), 2022). In the same ten-year period, an additional 233 km of railway lines were electrified, reaching 12,149 km in 2020. Despite the drop in the length of railway lines, the number of passengers transported increased from 262.3 million in 2010 to 335.9 million in 2019 (UTK, 2021a). In 2020, due to the COVID-19 pandemic, passenger transport declined to 209.2 million, showing a recovery trend in 2022 and exceeding pre-pandemic levels with 342.2 million passengers (UTK, 2023).

For rail to successfully compete with private cars, access to appropriate infrastructure is essential. The energy and fuel crisis provides additional reasons for developing rail transport in terms of energy efficiency. Rail can also be an emission-free mode of transportation, representing an essential element in reducing emissions of the entire transport sector. For instance, in France, rail transport, which accounts for 10% of traffic (freight and passengers), emits less than 1% of all GHG emissions from transport (SNCF Réseau, 2018). Rail transport is a key contributor to France's low carbon transition with the central role of SNCF Réseau, the French rail infrastructure operator. In 2020, rail transport in Poland had a 0.44% share in CO₂ emissions from the entire transport sector (Urząd Transportu Kolejowego, 2022).

Implementation

Accession to the EU enabled an increase in funding for the development and upgrading of railway infrastructure in Poland. In the first stage, between 2004 to 2013, its development was targeting mainly passenger transport.

Over the years, the technical condition of the railway infrastructure has generally improved. According to the Railway Traffic Safety Report from 2020, 63.1% of infrastructure was assessed as being in good condition, 20% in sufficient condition, 9.4% in unsatisfactory condition and 7.5% in poor condition (UTK, 2021b). Compared to the last four years, the percentage of railroad surfaces in satisfactory condition has increased by several percentage points. Furthermore, the share of railway lines with a maximum speed of more than 160 km/h was 2.1% and speeds in the range 120-160 km/h was 14.5%. Unfortunately, the share of lines with a maximum speed of 60 km/h or less is still high and amounted to 22% in 2020 (UTK, 2021b).

Thanks to the large-scale modernisation of the railway infrastructure and purchases of rolling stock co-financed by the European Union, the quality of rail services in Poland has improved significantly. Particularly noticeable is the development of the segment of intercity railway links that are competitive with air transport (e.g. Warsaw – Gdańsk, Warsaw – Kraków, Warsaw – Katowice, Wrocław – Katowice). There is a gradual improvement in the quality of service in the agglomeration transport segment, where Warsaw and Tricity (Gdańsk-Gdynia-Sopot) stand out above all. Other large

metropolitan areas such as the Upper Silesia, Poznań, Łódź, Wrocław and Szczecin are carrying intensive measures to develop the agglomeration railway.

In 2021, the national railway infrastructure manager, PKP PLK S.A., carried out investments worth around PLN 11.6bn (roughly EUR 2.5bn). The works included the modernization of approximately 915 km of track and more than 600 engineering structures (PKP PLK S.A., 2022). In Poland, the share of electrified lines amounted to nearly 63% in 2021 (Urząd Transportu Kolejowego, 2023). The layout of electrified lines is not optimal and ambitious plans for electrification were not completed – several corridors lack continuity in terms of rail electrification. Electrification makes most sense on railway lines with intense traffic.

Stakeholders

Although the rail transport market appears to be centralised, its complexity is reflected in its diverse actor structure. Railway infrastructure managers are key actors, implementing modernisation investments, carrying out revitalisation measures and are responsible for maintaining the railway infrastructure and charging for its provision. The public nature of rail infrastructure ownership translates into challenges for rail infrastructure managers. Long term predictability of funding and the mechanism for determining rail infrastructure access charges are particularly challenging due to the public nature of rail infrastructure. Public authorities are both beneficiaries and agents responsible for developing rail infrastructure at various levels. In some cases, even local authorities can play an important role in the process of revitalising local rail infrastructure (see the Box **Revitalisation of local railway lines in Poland**).

The construction sector is another crucial prerequisite for the development and maintenance of railway infrastructure and are key secondary actors in this space. Also, the growing importance of the NGOs advocating for policy changes cannot be neglected.

Level of implementation

There are different areas of action related to infrastructure that can increase activity levels for this mode of transport and shift traffic from more carbon-intensive modes of transport. Selected areas are described below.

Urban (metropolitan) railway

Urban rail transport can be a crucial element of the public transport system, connecting different cities and settlements. In Poland, this segment of the rail market presents excellent potential but lacks relevant institutional and legal frameworks. Many metropolitan areas are also taking steps to increase the share of rail transport in the passenger transport market.

The most spectacular example of a radical improvement in the quality of rail services in the metropolitan area in Poland was the commissioning of the Pomeranian Metropolitan Railway in 2015. It was built in the footprint of a railway line destroyed during the World War II and made it possible to connect Gdańsk with the suburban area while also serving the airport. The line is currently being electrified. Until the pandemic, passenger numbers grew significantly.

The metropolitan level of railway infrastructure provides enormous opportunities based on the diversity of many modes to be integrated and strengthened by the substantial passenger flows. Railways can also play a crucial urban-developing role, reducing the adverse effects of urban sprawl. In this dimension, integrated spatial planning is needed, emphasising the role of railway stops as multifunctional integration hubs.

Local and regional railway

The largest passenger transport segment in terms of the number of passengers carried is regional transport. Regional railway operations are managed and financed by voivodeship (province) governments. As a result of many years of infrastructure and rolling stock neglect, improving the quality of services in this segment is very diverse.

Due to the increasing popularity of car ownership, many local lines, most of which were used for daily commuting, have been abolished. Renovation and development of such connections offers the potential for a modal shift from road to rail. However, connections must be reliable and if possible, result in time and money savings for commuters. The impact of local train connections can be significantly increased if the stations are equipped with parking spaces for cars and bikes, preferably equipped with chargers for electric modes of transport. By integrating passenger car infrastructure, it is possible to motivate people to travel by train at least part of the journeys that would otherwise be fully covered by car.

Revitalisation of local railway lines in Poland

The local government of the Lower Silesian Voivodeship has taken a comprehensive approach to revitalising local railway lines. The regional infrastructure manager, Dolnośląska Służba Dróg i Kolei (DSDiK), has been taking over disused sections of railway lines for years and gradually restoring them to service through revitalisation projects with European funding. For example, on the restored and revitalised railway line No. 326 Wrocław Psie Pole – Trzebnica, 17 pairs of trains run weekly, some of which are hybrid trainsets.

Another good case of a railway revitalization process of the local network is the section of the railway line No. 356 (Poznań Wschód – Wągrowiec) located in the Wielkopolska region. Linear railway lines and station infrastructure was modernised with European funds through the Regional Operational Programme of the Wielkopolskie Voivodeship. New railway stops were developed, and existing ones were rebuilt. In cooperation with the infrastructure manager PKP PLK S.A., the modernised corridor is now characterised by higher spatial (integration hubs linking

local collective and individual transport) and temporal (more trains) accessibility. Improved services led to an increase in demand, from 1800 passengers per day before revitalization to 5400 passengers per day in 2018 and 2019. Also, the number of trains increased, from 11 pairs per day in 2011-2012 to 19 pairs in 2021-2022.

Railway infrastructure should be an attractive alternative compared to travelling by car. Existing rail connections lag behind other modes of transport in terms of comfort and journey times, which affects the preference for cars over rail travel. Moreover, the number of local connections does not meet the needs of the inhabitants, especially in smaller cities, which are often excluded from the broader transport network. In 2019, the Polish government adopted a resolution on the establishment of the Program for Supplementing Local and Regional Railway Infrastructure – Rail Plus, addressed to local government, which aims to enable the connection of voivodship cities with towns with more than 10,000 inhabitants with provincial cities by 2028 (Madras, 2019).

High-speed railway

The EU's well-developed rail network means considerable potential for growth in the role of rail in handling passengers transferred from air transport. However, it requires significant investment, as shown by the European Commission's ambitious plan to triple the length of High Speed Railway (HSR) lines by 2050.

Plans to develop the HSR network in Poland

In Poland, the development of HSR on a broader scale has not progressed beyond the concept stage (except for the so-called Central Railway Line, on which trains can travel at speeds of up to 200 km/h). Modernisation projects for the main railway lines under construction usually assume speeds of up mainly to 160 km/h. Given the distances between Poland's largest agglomerations, it is a reasonable compromise between travel time and investment expenditure.

The current development programme linked to the construction of the Central Airport Port (CPK) between Warsaw and Łódź includes the construction of the so-called ten "railway spokes" in perspective until 2040. There is controversy over potential passenger flows on some of them. However, the construction of "spoke" No. 9, which is an older concept of the so-called "Y line" connecting Warsaw, Łódź, Poznań and Wrocław, is beyond controversy. Also, an extension of the Central Railway Main Line (CMK) to Gdynia, including some cities with poor railway accessibility, is a crucial stage in the railway development process but discussion is being raised over the access to high-speed railway by several mid-sized cities. The planned operating speed in the first phase is 250 km/h.

The development of high-speed rail can be a factor in the integration of rail and air transport. Development of a joint transport offer in the catchment area of an airport offers opportunities for deepening cooperation between rail, air carriers and airports. In some cases, however, it requires the development of rail transport infrastructure to

serve the airport directly. This implies additional investment costs and requires time to design and build a direct connection. Therefore, combining air and rail presents potential where high-speed railway infrastructure is already operational.

Cross-border connections

Travelling across EU borders by train is still not as smooth as travelling by car or flying. In many cases change of trains is necessary or long waiting time at the border between the countries is required. One way to mitigate the issue is the creation of the Single European Railway Area. The European Commission has put forward a proposal for a European Partnership on Rail Research and Innovation, building upon Shift2Rail initiative, which fosters research and innovation in Europe's railway sector (*Europe's Rail*, 2022). Currently, it is possible to travel directly from Poland by rail to Germany, the Czech Republic, Austria and Slovakia. These connections are operated by Polish operators such as: PKP Intercity, Polregio and Koleje Dolnośląskie (Lower Silesian Railways) and Czech operators RegioJet and LeoExpress.

Several regional train operators in Poland develop cross-border connections on a local scale. For example, Koleje Dolnośląskie, an operator of the Lower Silesian Voivodeship, services the line between Szklarska Poręba Górna and Liberec (Czechia), offering nine pairs of trains per working day. The connection is an important factor of the cross-border development, including tourism.

However, there are several obstacles for development of rail infrastructure, namely: high entry barrier to the market for private operators, inability to purchase tickets for international travels online as well as lack of transparency around pricing. In many cases, the ticket purchases can only be made at the carrier's cash desk.

Proposed changes to the existing legislation

In addition to appropriate financing for developing rail transport infrastructure, Poland must provide adequate financial support for running public service obligations through railway transport. Efforts should be made to create mechanisms to support the current service offerings and integrate other means of collective and individual transport. Therefore, strengthening the economic position of regional governments responsible for the organisation and management of regional passenger transport is the most important challenge.

Barriers to the development of fast rail transport in agglomerations are the development and adaptation of connections, insufficiently quality of railway infrastructure, deficiencies in modern rolling stock to service agglomeration traffic, increasing costs of financing current operations, and complex tariff structure. A challenge in this context is also lacking cooperation between local governments across administrative borders to integrate or create new connections (Council of Ministers of the Republic of Poland, 2022).

In Poland there are at least seven metropolitan areas that differ formally and legally, operationally and economically complicating the supply side of public transport. Lack of common legal framework supporting integrated mobility in metropolitan areas is one of the most important challenges that regional governments are facing in Poland today. It directly impacts their financial ability to integrate different forms of public transport including municipal transport and railway transport.

Recommendations

The pyramid of mobility based on the railway system should be based on metropolitan and regional connections under public service obligations. The sensibly planned development of the railway infrastructure can be an essential factor in counteracting or limiting the adverse effects of suburbanisation. In this case, large-scale solutions (e.g. construction or large-scale modernisation of existing railway lines) should be sought, but parallelly, the focus should be on small-scale undertakings. An example is a construction of new railway stops, the immediate vicinity of which should be intensively developed by providing them with public services (schools, service centres for residents, shopping centres, etc.). At the same time, more train services should be subsidised to avoid a situation where only few pairs of trains per day run on a modernised railway line.

The development of high-speed rail as part of the European Union's transport policy should be carried out with long-term commitment and accompanying funding reflecting the future maintenance costs of the resulting system. It should be stressed that the amount of investment in the construction of high-speed rail infrastructure, as in the case of other large-scale infrastructure investments estimated at the stage of feasibility studies, may differ significantly from the actual values (Flyvbjerg et al., 2003)

Efficient and fast rail connections between cities in metropolitan areas are an essential factor in developing the competitiveness of rail services in cities and regions. Numerous studies point to the dynamic development of cities with high-speed rail links. However, care should be taken for cities along the high-speed rail line that this railway will not serve. The so-called 'straw effect' of syphoning off potential from areas with lower accessibility to cities with good high-speed rail provision may arise. The development of high-speed rail may reduce the need to develop domestic air links, which has an environmental benefit.

Conclusions

In addition to the physical dimension of the development of rail transport infrastructure, how it is provided is extremely important. The mechanism for shaping access to rail infrastructure varies between EU countries. Building accessible financing schemes is an important part of sustainable transport policy of each government. Therefore, the state's role in subsidising rail infrastructure development is essential to strengthen the rail supply against other modes of transport.

The share of rail transport in the emissions of the entire transport sector in Poland is very low. Due to their low emissions intensity, this mode of transport has a huge role to play and the potential to reduce emissions, especially in the service of metropolitan areas. Barriers that make it difficult to use the advantages of railways are formal and legal issues of integration of various subsystems of public transport and financial conditions in which local governments operate.

Electrification of bus fleets

Electromobility is a reasonable and natural step in urban transport development, facilitating a reduction in air pollution and traffic noise in cities. Electrification of bus fleets could be seen as an element of a wider strategy focused on dealing with climate change. Moreover, it could also be the first step in the deep electrification of the transport sector.

The aggregated demand in cities is fundamental to the operation model of public transport and a critical aspect of implementing electromobility in public transport. Based on designated routes, service breaks at specific points, and a time-tabled period it is possible to define the precise requirements to be met by the vehicles on a given route. At the same time, timetables can be managed in a way that allows to use the vehicles for as long as possible, for example by keeping the batteries at an appropriate charge.

Since 2015, the number of electric buses and other alternative buses operated in Poland has been steadily growing. In 2021 for the first time more new electric city buses were purchased in Poland than diesel buses (Jagiello et al., 2023). More and more cities are investing in electric vehicle fleets, using the entire range of available charging technologies (Mathieu, 2018) namely:

- only charging at the depot (overnight charging),
- charging only at the end of routes (opportunity charging),
- mixed charging at the depot and at the end of routes (mixed, overnight, and opportunity charging),
- vehicle charging while driving from the overhead line (IMC) (Lajunen, 2018); (Wołek, 2020).

Electrification of bus fleets is essential to accelerate the energy transition of urban transport systems. Urban transport is often the first area of the transport market to undergo electrification, and electrification contributes to lower emissions, especially when the electricity comes from renewable energy sources.

Implementation

According to the rules and objectives set by the Polish Act on Electromobility, the majority of cities in Poland started the electrification process of their bus fleets. They are purchased by the municipal public transport operators (or occasionally by cities themselves). The purchase almost always is co-financed from European and national funding. At the end of June 2023, the number of electric buses in Poland was to reach 950 (Weckwerth, 2022). Warsaw, Zielona Góra and Kraków have the most electric buses.

Electric buses in Jaworzno (Poland)

Jaworzno (roughly 92,000 inhabitants, Silesian Voivodeship) has an unusual spatial layout due to the city's historical development. It was formed from several former towns and villages in the 19th and 20th centuries. They do not create a uniform, coherent space and are separated from the area of the Jaworzno city centre. As a result, the population density is low for the city and amounts to about 604 people per square kilometre (Warsaw has a population density of just under 3,400 residents per km²). The mines and the power plant located in the centre of Jaworzno and next to the main national road shaped, an image of the city as highly industrial, with a polluted environment, and unattractive as a place to live.

The functional and spatial transformation, which began almost 20 years ago, included, among other things, the structural reconstruction of the transport system. It consists of striving for "vision zero" (seeking to eliminate fatal accidents involving pedestrians completely) in road traffic through restrictions on car traffic accompanied by the promotion of alternative forms of transport.

An essential part of a comprehensive approach to changes in the city is the increase in the quality of public transport. As of 2021, Jaworzno has the highest proportion of electric buses in urban transport in Poland. Electric buses provide almost 80% of the daily service on a weekday and the annual mileage of some of the city's electric buses exceeds 100,000 km. Electric buses in Jaworzno have become part of the city's strategy to reduce emissions and shape public transport in a modern way, and a cornerstone of the city's promotion in an international dimension.

Overhead charging is used in public transport primarily for trolleybuses and trams. Currently trolleybus design includes a set of electric batteries that enable the vehicle to drive independently without a permanent connection to the electric traction. After driving with the use of the overhead traction, the trolleybus continues its journey and carries passengers using the on-board electric batteries. Depending on the size of the battery pack, the trolleybus can travel from several to several dozen kilometres on the batteries alone, and many city routes are explicitly designed with this in mind.

The overhead line of the trolleybus is supplied with direct current with a rated voltage of 600 V (common in Poland) to 750 V (common in Germany), supplied by traction substations. Currently, there are three trolleybus systems in Poland in the cities of

Lublin, Gdynia, and Tychy. In total, there were roughly 10.7 million vehicle-kilometres driven by roughly 240 trolleybuses in the aforementioned systems in Poland.

Diversification of the electric urban transport fleet in Gdynia (Poland)

A good example of a city developing different forms of EVs in public transport is Gdynia (246,000 inhabitants). Apart from a well-developed trolleybus system (roughly 100 trolleybuses), the municipal company PKA Gdynia purchased 24 electric buses in 2022. The developed charging system includes an opportunity to charge in selected locations and overnight charging. The average battery capacity is 192 kWh for the standard bus (12 metres) and 250 kWh for articulated buses. These buses serve parts of the city mainly without a trolleybus network.

However, trolleybuses still form the core of urban electric transport in Gdynia, also serving neighbouring Sopot (a city with spa status). A breakthrough innovation in the development of trolleybus transport was the introduction of an in-motion charging scheme (IMC). Such technology usually means a smaller battery capacity than electric buses that can recharge in motion through a catenary.

From an operational point of view, the development of trolleybus transport in Gdynia and Sopot (Poland) depends on the ability of trolleybuses to travel independently using batteries. IMC operation provides an optimal solution between expensive investments in infrastructure and the size of the battery in a trolleybus. High-capacity batteries that provide long daily ranges for e-buses can account for up to 50% of the vehicle price. From financial point of view, IMC trolleybuses are recommended for cities already operating trolleybuses because of the effective compromises between energy consumption, service quality and battery capacity.

One of the most important features of trolleybuses (and e-buses as well) is their ability to recover energy through regenerative braking, increasing energy efficiency (Gao et al., 2017). Currently, IMC trolleybuses are regarded as part of the modern electromobility concept and are the most technologically ready, fully electric means of public transport receptive to further innovation (Wołek et al., 2020).

Case study analysis from Gdynia and Sopot confirms that the maximum length of catenary needed to make IMC trolleybuses fully operational and reliable is decreasing as battery capacity increases. The findings show that at least 30% of the catenary length is needed to maintain the flexible and seamless supply for IMC trolleybuses. The exact value depends on traffic conditions of a particular route and should be determined on a case-by-case basis. The off-catenary operations can be further extended when the charging power is increased from 120 kW to 250 kW (Wołek et al., 2020). The Gdynia and Sopot case study indicates that trolleybus transport can be increased without extending overhead contact lines.

In-motion charging technology optimises the costs of the battery size and capacity as the technology does not require the larger battery capacity to prevent the shortage of energy as with the classic battery-electric buses. Therefore in-motion charging brings an

original path for the expansion of the electromobility in urban areas without the additional challenge and cost of expanding overhead lines.

Stakeholders

The main stakeholders in the process of electrifying bus fleets are municipal governments. They determine development policies and identify the most critical challenges locally. Urban transport operators in Poland are another important stakeholder group, and they select the most economically advantageous technology for the given economic conditions (overnight charging versus opportunity charging or mix of both solutions, rarely in-motion charging, in case of three trolleybus systems in Poland) and its implementation in a manner that causes the least inconvenience to passengers. Local public authorities (self-governments) are responsible for setting up the strategies (including Strategy of Electromobility Development), and they provide the financial framework for the public transport service.

The transport authorities are the stakeholders most often responsible for creating the timetables, thus influencing the level of running costs of the technology to be implemented. Transport authority could also set a qualitative framework for the public transport operators. Furthermore, central government involvement is manifested in organising the legal framework and financing schemes for electrification, especially in the first period.

Implementation

In 2020 the National Fund for Environmental Protection and Water Management announced the "Green Public Transport" program. Its purpose is to co-finance activities in collective public transport that reduce the consumption of emission fuels. The financial support covered purchasing or leasing of new electric buses using only electricity as a drive system, purchasing or leasing of new trolleybuses, purchasing or leasing hydrogen buses and construction and/or modernisation of the infrastructure.

Additionally, the "Green Public Transport" program offered very attractive financing conditions. The program was initiated in 2020 and is planned for three stages (rounds) planned for the years 2021-2023. Actors can obtain subsidies of up to 80% of the purchase costs of new electric buses and trolleybuses, up to 90% of the costs of new hydrogen buses and up to 50% of the costs of modernization or construction of infrastructure. The project's budget for the first stage amounted to PLN 1.2bn (EUR 267 million).

In July 2021, the second call under the "Green Public Transport" program was announced, aimed at supporting the organisers of public collective transport in the purchase of new zero-emission buses, including trolleybuses and buses powered by electricity generated from hydrogen, and the development of charging infrastructure. Local governments and their companies can apply for funding from 20 to 80% for the purchase or leasing of such vehicles, drivers' trainings, and up to 25% for the development of charging infrastructure which could include construction of new or

modernization of existing charging stations. Support is directed to cities, especially smaller ones and losing their socio-economic functions, struggling with the problem of air pollution, as well as local governments that eliminate the phenomenon of transport exclusion through the development of local government transport (PAP, 2021).

Currently, buses with hydrogen fuel cells in Poland are very rare due to the lack of refuelling infrastructure and unstable hydrogen prices. Several projects are on the way, especially in close collaboration with large chemical companies. In the next years it is expected that nearly 100 hydrogen buses will be operating in Polish cities.

However, mass electrification raises several challenges, among which the availability of relatively cheap electricity now comes to the forefront. In a time of energy crisis, a conscious and responsible central government policy of minimising the negative impact of high electricity prices is crucial to sustaining the development of electromobility in public transport.

Poland mainly relies on fossil fuels for electricity generation, which raises concerns about the environmental benefits of using electric public transportation. Linking the development of renewable energy sources (especially at the local level), electricity storage and electrification of bus fleets is an effective strategy for tackling climate change. Local renewable energy sources can be harnessed by establishment of photovoltaic farms. These farms can transfer electricity directly to the tram and trolleybus networks. One such project is currently being implemented in Gdynia. By installing solar panels on the 0.5-hectare roof of the trolleybus depot's parking square, the annual electricity demand of 100 trolleybuses can be met with 5% solar power.

Conclusions

Electrification of urban transport is a reasonable and natural step in its development. Public authorities are poised to support electrification, which can be the first stage of the energy transition of the urban transport sector. As there are different technological strategies of electrification (overnight charging, opportunity charging, mixed, in-motion charging), they have a diversified impact on the way vehicles are exploited and for the requirements for battery parameters.

Although the electrification of public transport is seen as one of the most efficient ways to decrease emissions, the current energy market situation means massive challenges for the operators. The challenge for the continuation of the electromobility revolution in public transport is the volatility of electricity prices. Costs are also in flux – unstable demand due to COVID-19 resulted in lower fareboxes and higher subsidies from the public budget. Therefore, an urgent central government intervention is needed to prevent a regress of the electrification process.

Integration of rail and public transport

Since the fall of Communism in Poland over 30 years ago, it has not been possible in Poland to integrate fares for urban transport and rail transport, and to ensure funding to the extent that these subsystems are fully integrated. The situation is even more difficult in metropolitan areas combining various territorial, functional, and spatial subsystems. Nevertheless, some regional and local governments tried to integrate fares for municipal and railway transport. However, positive examples of systemic solutions remain scarce.

The revitalisation of public transport after more than two years of pandemic-induced collapse is a huge challenge. However, it also creates room for implementing new solutions to deepen integration, especially between rail and urban transport organised by local authorities. As well as creating a more attractive alternative to the private car, integration also means improving the accessibility of areas with higher levels of social exclusion, integrating them into the local and regional socio-economic system.

Stakeholders

The leading players are city governments, which are the centre of a metropolitan or functional area. As a rule, these are large cities with significant organisational and financial potential. Rail transport operators set up by local or regional governments can also be essential in the integration process (see the **box below**). Local authorities are also necessary, albeit underestimated partners, and can subsidise integration processes if only to a small extent - not only through direct subsidies but also through investments to improve the intermodality of local transport hubs.

Łódź Agglomeration Railway - the backbone of the creation of an integrated transport system (Poland)

An interesting example is the city of Łódź, which, since 2017, has been recognizing local public transport tickets for trains of the Łódź Agglomeration Railway. The annual cost of integration is roughly PLN 4.5 million (EUR 1 million). The core for the integration was development of Łódzka Kolej Aglomeracyjna – the railway operator owned by the self-government of Łódzkie voivodeship. Moreover, in cooperation with the city of Warsaw, an offer has been created for passengers who will purchase a Łódź Agglomeration Railway ticket from Łódź to Warsaw, enabling the use of Warsaw public transport for 75 minutes in the 1st ticket zone (City of Warsaw, 2022a).

Implementation

At present, the implementation of integration solutions takes place at the metropolitan level (one case of the GZM Metropolis in Silesia) or in the form of an agreement between local authorities. One municipal transport tariff has been operating since 2018 in the Silesian Metropolis GZM, covering 41 cities and communes located in the centre of the Silesian Voivodeship. As a result, residents can purchase a shared train, bus and

tram ticket, which facilitates mobility in this area (Rösler, 2021; The Upper Silesian-Zagłębie Metropolis, 2022).

Ticket integration in Warsaw Metropolitan Area

Although there is a lack of integrated legal framework supporting integration between rail and other forms of passenger public transport, many cities tried to develop their own solutions. Warsaw has integrated tariffs for passengers purchasing selected tickets of the Public Transport Authority (ZTM Warszawa), thanks to which passengers can travel by suburban trains in Warsaw and neighbouring municipalities (City of Warsaw, 2022b).

Warsaw also offers a PKP Intercity Warsaw Ticket and a Warsaw Ticket with Polregio, on the basis of which passengers can use all means of Warsaw Public Transport for 75 minutes in the first ticket zone and in the second case, for 90 minutes in the 1st and 2nd ticket zones (City of Warsaw, 2022c).

ZTM (Warsaw public transport authority) season tickets – from day tickets upwards – allow travel by train without additional surcharges. This offer has significantly increased rail use in Warsaw and in the whole metropolitan area.

A new contract assumed a surcharge on around 6 million train-kilometres of two train operators. The transport authority for Warsaw - ZTM will pay nearly PLN 200 million this year for honouring tickets.

Proposed changes to the existing legislation

The concentration of inhabitants in metropolitan areas with depopulation on a subregional and local level is one of the trends affecting Poland. It creates multi-level challenges for the space within metropolitan areas as the main area with population concentration. In response to such a situation, the proper management models for metropolitan areas and development of collective public transport should be prioritised. The only act on metropolisation so far has been applied only in Upper Silesia and Zagłębie Metropolis (Silesia Region). Lack of a common legal framework supporting integrated mobility in metropolitan areas is the biggest problem that regional authorities are facing in Poland today. It directly impacts their financial ability to integrate different forms of public transport (municipal transport, railway transport).

Also, the systemic weakening of the financial independence of local authorities in Poland will result in their lower ability to finance projects to deepen the integration of urban and rail transport.

Co-benefits

There are extensive benefits from deepening integration between urban and rail transport. These include the reduction of spatial chaos resulting from the suburbanisation processes. This includes increasing the attractiveness of integrated public transport and contributing to creating an attractive alternative to the private car

and thus reducing emissions. Additionally, transforming bus stops into centres to integrate different transport subsystems positively impacts the surroundings and increases the attractiveness of public space.

Conclusions

There is no stable and transparent legal framework that would enable convenient integration of tickets for rail and urban transport in Poland. Despite this, large cities still try to develop their own solutions based on the agreement with selected regional railway operators. The most successful case is Warsaw, but the cost of such integration is high. Typical challenges facing potential agreement are method of compensation calculation, value and length of the contract. Through higher levels of ticket integration, public transport can become more appealing to the population, particularly those that often travel within a specific region. Further cooperation between city governments, public transport providers, and rail operators can also help strengthen the legal arena and build networks that can be leveraged to further decarbonise passenger transport.

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