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DIVERSIFICATION OF POLICIES FOR THE DEVELOPMENT OF ELECTRIC PUBLIC TRANSPORT IN THE CZECH REPUBLIC, POLAND AND SLOVAKIA

Zróżnicowanie polityk rozwoju elektrycznego transportu publicznego w Czechach, Polsce i na Słowacji

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Abstract: Urban transport in countries of East-Central Europe, including the Czech Republic, Poland and Slovakia, played an important role in the residents' daily mobility. The underdevelopment of individual motorisation contributed to the lasting significant role of public transport. Due to the operating characteristics of electric vehicles, as well as emerging fuel crises, electric public transport played a key role, especially in large cities. Differences in the development of economies in the electrotechnical segment influenced the structure of public transport in the analysed countries. The higher level of development of the Czechoslovak transport sector contributed to a greater share of trams and trolleybuses in total transport. Despite many development plans in Poland, the process of developing traditional means of electric transport slowed down with the political change in 1989. The situation was slightly different in the Czech Republic and Slovakia, where, despite financial difficulties, the development of tramway and trolleybus networks continued. Modernisation of public transport began after joining the European Union. Technological development has led to the emergence of a new means of transport –electric buses. The apparent ease of putting them into service revolutionised the situation in Poland, thus popularising electric transport. The situation was different in the Czech Republic and Slovakia, where the main focus was on the development of tramway and trolleybus transport. The article reconstructs the development of urban electric transport after 1989 in the analysed countries and identifies factors that differentiate contemporary transport development policies in the Czech Republic, Poland and Slovakia.

Keywords: public transport, electromobility, trolleybus, tramway, electric bus, transport policy

1. Introduction

Countries of East-Central Europe – the Czech Republic, Poland and Slovakia – have followed a similar path of socio-economic transformation from the communist system to the democratic one. They undertook activities related to economic reforms and joined international organisations, such as the European Union, at the same time. Nowadays, the foundation of their functioning is the common socio-economic policy of this community, and the actions it creates determine the development of individual countries. The transport sector is an important area of EU activities. Due to the fundamental economic importance, many activities undertaken by the institutions of the European Union concern transport issues. These include both the development of various modes of transport, as well as initiatives related to counteracting climate changes. The transport sector is responsible for a significant share of the emission of pollutants and CO_2 to the atmosphere, and in this respect it has a special place in strategic documents of the European Union and the member states. Due to the negative impact on the environment, solutions have been adopted to substantially reduce the emission performance of transport. The main demands include the development of emission-free modes of transport and, in the long term, a complete departure from means of transport powered with fossil fuels. Public transport has become an important recipient of these solutions due to the earlier use of electric vehicles. These were classic means of urban public transport, such as trams, trolleybuses and the metro. Nowadays, due to technological development, both classic means of transport and new ones – electric buses – have been transformed (Pieregud, 2019). New solutions allow trams and trolleybuses to be partially independent of the traction infrastructure, which facilitates the development of connections in areas with low population density and low demand for transport services or in places where it is impossible to build overhead traction, e.g. in districts with historic buildings. Simultaneously, there is the issue of competition from electric buses completely independent of the traction infrastructure, which may lead to a decline in traditional means of urban electric transport (Taczanowski et al., 2018; Wołek et al., 2020).

There were noticeable differences in the development policies for electric public transport in Czechoslovakia and in Poland during the communist period. The higher level of development of the electrotechnical industry in Czechoslovakia than in Poland resulted in greater popularity of trolleybus transport (Stepanov, 2019). It was a period of activity of two very important manufacturers of tramway (Tatra) and trolleybus (Škoda) rolling stock which dominated the supplies within the Council for Mutual Economic Assistance (CMEA) (Goliszek, Połom, 2015; Połom, 2017). In the 1980s, the development of electric transport was also planned in Poland, but most plans were not implemented due to the lack of adequate financial resources nor technical possibilities (Połom, 2019). As a consequence of these policies, many trolleybus systems were inherited by both the Czech Republic and Slovakia. Some of them were being designed or built in 1989, so with the onset of the process of the collapse of the communist system, i.e. the centrally controlled economies in East-Central Europe, the plans were not abandoned and were finally implemented. Thus, the number of trolleybus systems in the Czech Republic and Slovakia increased in the 1990s. Such a phenomenon did not take place in Poland, which, together with the political transformation, completely reorganised the public transport system after 1989, delegating the responsibility and financing from the central budget to local government units. It was only in 2015, mainly thanks to EU funds, that the first new system of traditional electric transport (tramway) was launched in Olsztyn (Beister et al., 2015). The lack of an established position of tramway and trolleybus transport in Polish transport policies and insufficient financial resources resulted in a certain collapse of some systems, i.e. shutting down of tramway communication in some towns of the Łódź agglomeration and the Katowice conurbation, as well as of trolleybuses in Dębica, Słupsk and Warsaw. The systems in Gdynia and Tychy were also in danger of being closed down (Połom, 2019).

2. Aims, methods and data

During the communist regime, urban electric transport was essential in the analysed countries in ensuring the daily mobility of urban centres, especially large ones. The underdevelopment of individual motorisation, a lack of possibilities to buy a private car on the open market, and the necessity to wait for one's turn for several years to buy it from a manufacturer made public transport the basic means of transportation. Due to a higher level of technological development of the Czechoslovak economy compared to the Polish one, a significant share of transportation was carried out by means of electrified transport. On the day Czechoslovakia was divided into two separate countries, the population was 15.6 million. For comparison, in 1993 there were 38.4 million inhabitants in Poland. At that time in Czechoslovakia, there were 18 trolleybus, 9 tramway and 1 metro system in Prague, while in whole Poland only 5 trolleybus and 14 tramway ones (Beister et al., 2015; Połom, 2019).

Differences in the place of electric urban transport in the policies of the Czech Republic, Poland and Slovakia, as well as experience in the operation and development of traditional means of zero-emission transport, resulted in diversified plans for further actions. In Poland, electric buses have become very popular, and they were willingly implemented in public transport after 2015. Electric buses grew in popularity even in centres with well-functioning tramway and trolleybus systems. The situation was slightly different in the Czech Republic and Slovakia. Due to the relatively large number of cities with trolleybuses and tramways, electric buses did not gain so much popularity as in Poland.

By analysing the differences in policies for the development of urban electric transport in the analysed countries, an attempt was made to identify the factors affecting these activities and to reconstruct the dynamics of changes in public transport after 1989. With this in mind, a four-stage research procedure was implemented (Fig. 1).

In order to achieve the assumed research goals, the following research questions were put forward:

1. was the development of tramway and trolleybus transport in the Czech Republic, Poland and Slovakia at a similar level in 1989-2020?
2. what system differences influenced the development of urban electric transport in the analysed countries?
3. to what extent, in particular in the field of on-board power sources (traction batteries), did technological development contribute to the popularisation of emission-free transport?
4. are electric buses a threat to the development of traditional urban electric transport systems (tramways and trolleybuses) in the analysed countries?

In this research on urban electric transport in the Czech Republic, Poland and Slovakia, statistical analyses were based on the official yearbooks of associations of public transport operators, scientific publications, strategic documents and unpublished materials.

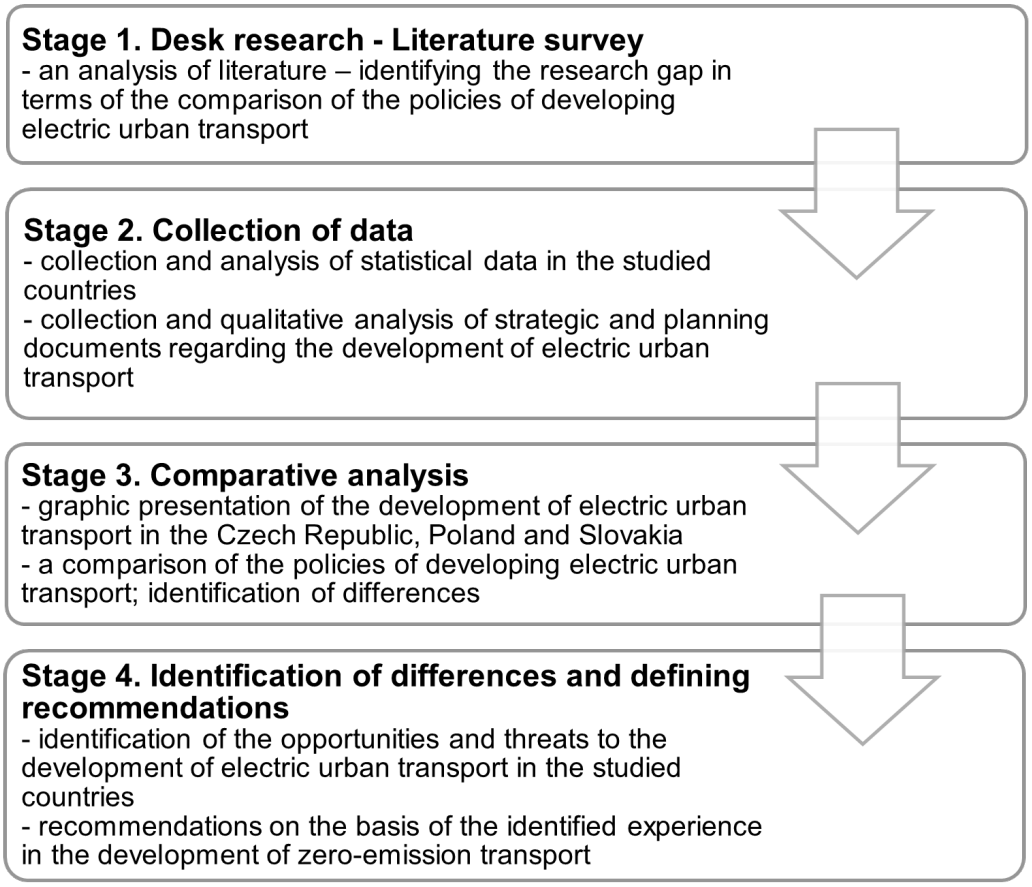

Fig. 1. Stages of the research procedure.

Source: own study.

3. Scientific framework

Public transport is an important research issue due to its importance in the daily functioning of societies. It is common in urban areas, in all large and very large cities, as well as in most medium-sized and even small ones. Traditional means of transport typically include buses, trams and trolleybuses, as well as metro and city rail systems. This article analyses in detail the development of electrified transport systems – tramways and trolleybuses – as well as the impact of technological development on their subsequent functioning and competition from electric buses.

Tramway and trolleybus transport was characterised by periods of varied popularity. At the beginning of the 1960s, they were closed down on a large scale, the motivation being their inadequate technological adaptation to the requirements of the time. Both means of transport grew in popularity in times of fuel crises, when it was much easier to use electricity (Pucher, Buehler, 2005; Costa, Fernandes, 2012; Vozyanov, 2017). Although the energy mix in the countries of East-Central Europe varies, and it is definitely unfavourable in Poland, where electricity is produced mainly from fossil fuels, the fact that there is no emission of pollutants at the place of use, especially in areas with high population density and significant congestion, is of key importance (Čechovič, Kendra, 2018). Pro-ecological solutions related to the use of low-emission and zero-emission vehicles are promoted by the European Union, whose transport policy expects a complete departure from vehicles powered by fossil fuels (Burchart-Korol et al., 2020; Cansino et al., 2018). Adaptation to the EU policy is implemented at the central level in all the analysed countries (Daňo, 2018; Hrudkay, Jaroš, 2020; Knapčíková, 2019). Reduction of emissions of CO_2 and of other pollutants into the environment is crucial (Tucki et al., 2019). With this in view, solutions involving buses powered with natural gas, electricity, hydrogen and hybrid ones are proposed, as well as the development of tramway and trolleybus transport (Jurkovič et al., 2020; Sendek-Matysiak et al., 2020; Skrúcaný et al., 2019; Ślusarczyk, 2020). The use of low-emission transport is important in improving living conditions in cities (Khairullina, Santos y Ganges, 2020; Michniak, 2020; Rišová, Pouš, 2018; Trembošova et al., 2020). The amount of budgetary funds allocated for these purposes is of key importance for the development of electrified transport in the post-communist countries of the European Union. The costs of implementation of classic means of electrified transport are initially higher than of bus transport, including fully electric ones. Very often, studies of economic efficiency of the process of vehicle implementation are carried out, but long-term operation is not analysed (Živčák et al., 2020). In this case, tramways and trolleybuses could often win depending on many conditions, including the volume of demand for services (Fitzová et al., 2018; Mikušová et al., 2018; Fitzová, Matulová, 2020; Pietrzak, Pietrzak, 2021).

While analysing the collected literature, a research gap was identified in terms of comparing the policies for the development of public transport in cities of various countries of the region, in particular as regards electrified transport. This issue is important for finding the best development path, based on the experiences of economies and societies that have a similar history.

4. Result

4.1. Experiences in the functioning of urban electric transport

Urban electric transport was developing at a different pace in the analysed countries. While the dynamics of development in Poland slowed down at the beginning of systemic changes, despite financial difficulties, it continued in Czechoslovakia, and then after the division of the country in the Czech Republic and Slovakia. In 1989, there were 6 trolleybus systems in Poland, which experienced difficulties in the subsequent years (Fig. 2).

Due to higher operating costs, worn-out rolling stock and degraded infrastructure, measures were taken to end the operation of trolleybus transport. This process concerned all networks, with the first one shut down in Dębica. It was an unusual route, practically serving the employees of large Igloopol plants in Straszęcin. Due to the collapse of the company and its liquidation in 1991, trolleybuses were suspended already in 1990. Then the line connecting Piaseczno near Warsaw with the capital was closed down in 1995. Since 1997, actions were taken in Słupsk to stop trolleybus transport, which was finally done in 1999. Similar problems concerned the other three systems – in Gdynia, Lublin and Tychy. The greatest difficulties concerned the smallest of them – Tychy (Borowik, Cywiński, 2016; Połom, 2019). Finally, due to social resistance, the trolleybus communication was not closed down. The larger systems in Gdynia and Lublin were too extensive to be easily dismantled and replaced by buses. Waiting out the difficult period until Poland's accession to the European Union allowed fully modernising all three networks in subsequent years, and then developing them dynamically, both in terms of the number of connections and the passenger volume (Połom, 2018; Wołek et al., 2021). As regards tramway transport, the situation was slightly different. All networks experienced difficulties, but

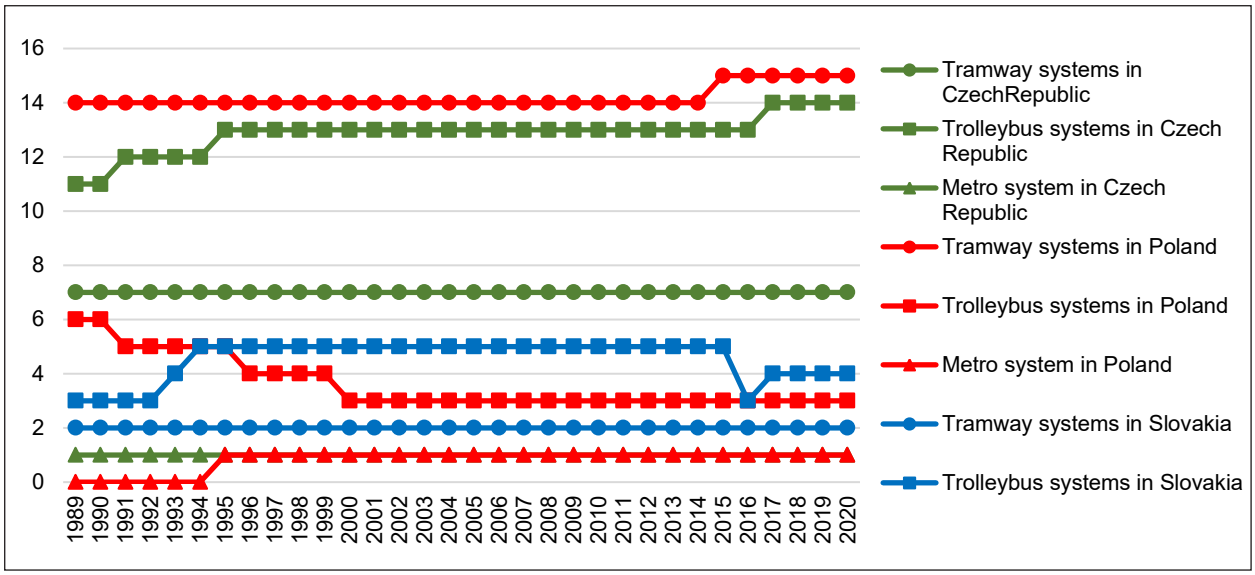

Fig. 2 Number of urban electric transport systems in the Czech Republic, Poland and Slovakia.

For the entire period 1989-2020, the current political division was adopted without taking into account the existence of Czechoslovakia until 1993

Source: Połom (2019), Stepanov (2019), Trolley: motion (2021).

none of them was closed. Single routes were phased out, in particular on the border of two or more towns (the Łódź agglomeration and the Katowice conurbation). In 2015, after 50 years, tramway transport was restored in Olsztyn. This is the only example of building a new system from scratch, not including the Warsaw underground, which was launched in 1995 after many years of construction.

The situation was slightly different in Czechoslovakia. Due to the higher level of technological development (in the field of power electronic drives and traction infrastructure) and the size of the scale (the number of existing urban electric transport systems), trams and trolleybuses were in a relatively good situation. Their position was also strengthened by the existence of local, but internationally recognised factories producing rolling stock. In 1989, Czechoslovakia had the Prague metro system, which was launched in 1974, as well as 9 tramway and 14 trolleybus networks. All tramway systems were put into operation at the turn of the 19th and 20th centuries. The youngest of them was launched in Košice in 1913. Since then until the present day, no new tramway networks have been created in the Czech Republic and Slovakia. Trolleybus transport was characterised by a different dynamics of development than trolleybus transport. At the beginning of the 20th century, four systems were launched, but they were liquidated quite quickly (in the second decade). The reason was the technological underdevelopment and the deficiencies of solutions. Subsequent networks were created during World War II, which, as in Poland, was associated with fuel problems. The largest group of trolleybus networks was launched in 1946-1963 (12, including one technical system for the Škoda trolleybus factory in Ostrov, which existed in 1963-2004). Of all the networks, two were closed down: one between the towns of Most a Litvinov, due to the transformation of the connection into a tramway one, and the other one in Děčín, on the wave of liquidation of trolleybus transport in Europe at the turn of the 1960s and the 1970s. Then, in the following years, the construction of many trolleybus systems was planned, of which six were eventually built. Despite advanced design works, trolleybus connections in Karlovy Vary, Kladno and Třebíč were not launched. In recent years, trolleybus connections in Košice, Slovakia, were also suspended in 2015 due to the wear and tear of the rolling stock. Despite maintaining of the traction infrastructure and the power supply system in full readiness, restoring trolleybus services has not been successful yet, although simultanously all Slovak trolleybus networks have been undergoing a process of modernisation and development.

4.2. Diffusion of innovation – implementation of electric buses

The underinvested tramway and trolleybus transport has been receiving support from European funds since 2004. Therefore, it was possible to modernise power systems, tracks, traction network, and above all, workshop facilities and rolling stock. In addition to restoring the technical condition, which made traveling safer and more comfortable, many investments

were made to increase spatial accessibility to electric public transport. Due to the economic difficulties in the 1980s and as a result of the political transformation in the 1990s, investments aimed at supplying new housing estates with tramways and trolleybuses were abandoned. Therefore, there is certain injustice in access to environmentally friendly means of transport. With the technological development, which peaked in the two decades of the 21st century, there has been a change in the approach to urban electric transport in East-Central Europe. It has become possible to flexibly shape trolleybus transport, first thanks to combustion units, and then batteries installed in vehicles. Making trolleybus transport independent of the traction network has led to an improvement in its financial results, no need to maintain a reserve in the form of diesel buses and to the extension of connections to areas with a lower population density, with lower demand for communication services or to places where it is difficult or impossible to build the traction infrastructure. The city of Hradec Kralové was the first in the analysed countries to use such a solution. In 1994 a trailer with an internal combustion engine pulled by a trolleybus was constructed. It enabled powering the vehicle's propulsion system at the short end section where the construction of the traction network was difficult. Good experience with the operation of such a solution in 1994-2001 led to the construction of new, low-floor Czech-made trolleybuses – Škoda 21TrACI. In the following years, vehicles of this type appeared in Pilsen. Similar solutions were developed many years later, when Škoda started cooperation with the Polish factory Solaris, and jointly they supplied trolleybuses to the European market (e.g. to Lublin). The technology of the combustion unit gave flexibility to trolleybus transport, but at the same time it reduced its advantages related to the lack of pollutant emissions. Modern battery solutions which the Polish company Solaris began to implement gave a new development impulse to both trams and trolleybuses. Installing a battery in trolleybuses enabled covering sections of routes without a need for power supply from the electric traction. On the one hand, it gave a possibility to freely modify the route; on the other hand, it made transport more flexible in emergency situations. The first trolleybuses of this type in the studied area were put into operation in Gdynia (Solaris, 2009) and in Mariánské Lázně (Škoda, 2004). In the following years, the battery solution became common, and it replaced combustion units. Thanks to the development of battery technology, increasing their capacity while reducing weight and extending the service life, it has become possible to use trolleybuses on the peripheral sections. Thanks to diesel generators and on-board batteries, trolleybus connections were developed in most of the analysed cities. The development of on-board battery technology has also become an impetus for tramway transport. The first vehicles equipped with an additional source of electricity began to be put into operation in Gdańsk, Poznań and Kraków. Ultimately, such a solution will allow for a partial resignation from the traction network, e.g. in historic city centres.

The development of electric urban transport based on electric buses should be assessed separately. These have appeared on a large scale in the analysed countries since 2015. The dynamic development of battery technologies allowed for full electrification of city buses. However, this is a much more complex process than installing them in trolleybuses. In the case of electric buses, it is necessary to equip them with a much larger power source, which significantly reduces the vehicle's capacity and also affects the costs of its operation (e.g. battery replacement during the life cycle of the vehicle). The seemingly easy implementation of electric buses in public transport and numerous possibilities of co-financing their purchase from the state budget or EU funds resulted in enormous interest of cities in such a solution. At the end of 2020, electric buses were operated in 18 towns of the Czech Republic (Bíilina, České Budějovice, Frýdek-Místek, Havířov, Hradec Králové, Hranice, Karviná, Krnov, Kutná Hora, Nový Jičín, Náchod, Ostrava, Písek, Praha, Třinec, Trutnov, Uherské Hradiště, Vrchlabí), and in 5 in Slovakia (Banská Bystrica, Bratislava, Košice, Šaľa, Žilina) (Fig. 3). Out of 23 towns, 8 had previously had other means of electric transport. The remaining towns are small in terms of the population number and do not have the experience and facilities needed to operate electric buses, which may cause difficulties in their operation in the future.

In recent years, the Polish government has shaped the policy of development of public transport, particularly in terms of electric buses. A number of programs and projects supporting the purchase of such vehicles by even the smallest towns has led to a departure from traditional means of electric transport. In 2015, the first tramway network was launched in over 50 years in Olsztyn, but there are no other plans of this type. Nowadays, both cities with trams and trolleybuses and other cities in which public transport was based on diesel buses redirected their development policies to electric buses. The Polish legal framework assumes that, since 2025, all vehicles that will be put into operation in public transport must be zero-emission, and therefore powered by electricity. However, the activities of the Polish government have led to a number of disruptions in treating traditional means of transport equally, in particular trolleybuses, due to the inability to use certain aid funds. At the end of 2020, electric

Fig. 3 Electric urban transport systems in the studied area as of the end of 2020.

Source: own elaboration based on Beister et al. (2015), Połom (2019), Trolley: motion (2021), Wołek, Wyszomirski (2013).

buses were in operation in 27 towns, including 5 which had previously had tramway systems.

4.3. Organisational conditions for the development of urban electric transport

Public transport plays an equally significant role in the three analysed countries, but the organisational and legal conditions are different. In Poland, the trolleybus has been defined in "Prawo o ruchu drogowym" [Eng.: Road Traffic Law] (Act of 20 June 1997), where it was recognised as a road vehicle similar to a bus (a variation of a bus). The technical and operational conditions for trolleybuses were defined in "Rozporządzenie Ministra Infrastruktury z dnia 2 marca 2011 r. w sprawie warunków technicznych tramwajów i trolejbusów oraz zakresu ich niezbędnego wyposażenia" [Eng.: the Regulation of the Minister of Infrastructure of 2 March 2011 on the technical conditions of trams and trolleybuses and the scope of their necessary equipment] (2011). In Poland, trolleybuses are registered similarly to city buses; they are homologated both as road vehicles (trolleybuses) and electric drives, and they are must bear registration number plates. Due to the limitations related to obtaining external funds, trolleybuses in Gdynia (and those planned for purchase in Tychy) are an exception, as they have double homologation as electric buses and trolleybuses. The willingness to buy an electric bus was a necessary condition to obtain funds from the government project "Gepard", which unfairly treated trolleybus transport. The solution was to create a trolleybus that has the characteristics of both an electric bus and a trolleybus. The drive is powered only by on-board batteries which are charged while the vehicle is in motion connected to an overhead line. However, the drive system is never directly supplied from it.

The legal situation in the Czech Republic and Slovakia is different; trolleybuses there do not have registration number plates. In the Czech Republic, the trolleybus, including the hybrid bus, is defined as a motor vehicle, including a road vehicle, but is included in the classification of motor vehicles in Zákon č. 56/2001 Sb (2001) [Eng.: Act 56/2001 Coll.]. The trolleybus is treated as a rail vehicle and is subject to the jurisdiction of institutions approving this

type of vehicles. In this case, the definition classifies the trolleybus as a vehicle running on a (trolleybus) track. Nevertheless, as in Poland, a category D (bus) driving license is required to drive trolleybuses. The situation identical to the one in the Czech Republic prevails in Slovak legislation. Trolleybuses are also road vehicles, but are not registered as buses (they do not have vehicle registration plates).

In addition to legal issues, the tradition of financing electrified transport in cities is also important. Due to the European Union's transport policy, electric vehicles are preferred. However, there was no such framework in the past, and national policies varied in this respect. The purchase of trolleybuses is much more expensive than of diesel buses, due to the long service life of electric vehicles, as well as customised unit production. Without external support, the cities found it difficult to renew their vehicle fleet. This situation differentiated Poland from Czechoslovakia. While after the accession to the European Union there were aid funds that facilitated investments in urban transport, in the previous years, the expenses had been covered by cities. In Czechoslovakia, there was government support for the purchase of trolleybuses also after 1989. Similarly, after the division of the country, such opportunities were maintained in the Czech Republic for some time.

Nowadays, funds from the European Union as well as the national framework for supporting the development of electromobility are the main methods of financing investments in the field of urban electric transport. Legislation in each of the analysed countries introduces measures aimed at eliminating diesel vehicles from public transport and supporting the purchase of electric buses, trolleybuses and trams.

4.4. Identification of policies for the development of traditional means of urban electric transport in the Czech Republic, Poland and Slovakia

Despite socio-economic similarities of the three analysed countries, their approaches to the development of urban electric transport differ. During the communist period, Czechoslovakia was characterised by greater stability in the functioning and development of urban electric transport. At that time, many trolleybus systems were created, and few of the existing ones were closed down. In the same period in Poland, despite a much larger scale, electric transport did not develop as dynamically. Apart from the government's policy, this was also due to the operation of tramway and trolleybus manufacturers in Czechoslovakia, and above all, a higher level of technological development. After the communist period, both countries experienced economic difficulties, and, additionally, Czechoslovakia split into two separate states. Nevertheless, electric transport in cities continued to play a key role; its scale was larger than in Poland, and the investments initiated in previous years were continued, which resulted in the creation of new trolleybus networks in České Budějovice, Chomutov, Košice and Žilina. In Poland, the 1990s brought about the closure of three trolleybus networks and potential discontinuation of the three remaining ones. The situation changed only after the accession of East-Central European countries to the European Union. At that time, Polish cities began to modernise public transport very dynamically, and tramway and trolleybus networks became exemplary in terms of development as well as modernisation of infrastructure and rolling stock. The fact that Poland became the largest beneficiary of funds from the EU budget was of great importance in this process. This huge development opportunity was used with a surplus. The main examples of the effects of this policy include the emergence of manufacturers of trams (Modertrans, Newag, PESA, Solaris) and trolleybuses (Solaris, Ursus), as well as the implementation of advanced technological innovations.

The present article attempts to identify transport policies for the development of urban electric transport in the Czech Republic, Poland and Slovakia. With this in view, the content of websites of all tramway, trolleybus and electric bus operators was analysed, as well as statistical yearbooks of public transport chambers (Komunikacja miejska w liczbach 2015, 2016, 2017, 2018, 2019, Osobná mestská doprava 2015, 2016, 2017, 2018, 2019, Výroční zpráva za rok 2015, 2016, 2017, 2018, 2019). The collected data was aggregated according to six categories for traditional means of public transport – trams and trolleybuses: in terms of the development of infrastructure (construction of new routes), modernisation of infrastructure (the existing one), development of connections (new sections of existing routes or new communication lines), purchase of new vehicles (trams or trolleybuses), closure of connections (elimination of communication lines without launching a new connection on this route) and physical removal of infrastructure (Tab. 1).

Tab. 1. Identification of elements of transport policies (in 2011-2020) in cities with tramway and trolleybus systems.

Country	City	Means of transport	Development of infrastructure	Modernisation of infrastructure	Development of connections	Purchase of new vehicles	Closure of connections	Removal of infrastructure	Comments
Czech Republic	Brno	tramway	•	•	•	•	•	•	
		trolleybus	•	•	•	•			
	Chomutov a Jirkov	trolleybus		•		•	•	•	
	České Budějovice	trolleybus		•		•	•		
	Hradec Králové	trolleybus	•	•	•	•			
	Jihlava	trolleybus	•	•	•	•			
	Liberec	tramway		•		•			
	Mariánské Lázně	trolleybus	•	•	•	•			
	Most a Litvinov	tramway		•		•			
	Olomouc	tramway	•	•	•	•			
	Opava	trolleybus		•	•	•			
	Ostrava	tramway		•		•			
		trolleybus	•	•	•	•			
	Pardubice	trolleybus	•	•	•	•			
	Plzeň	tramway	•	•	•	•			
		trolleybus	•	•	•	•			
	Praha	tramway	•	•	•	•			
		trolleybus	•		•	•			New system launched in 2017
	Teplice	trolleybus	•	•	•	•			
	Ústí nad Labem	trolleybus		•		•			
	Zlín a Otrokovice	trolleybus		•	•	•			

Poland	Bydgoszcz	tramway	•	•	•	•			
	Częstochowa	tramway	•	•	•	•			
	Elbląg	tramway	•	•		•			
	Gdańsk	tramway	•	•	•	•			
	Gdynia-Sopot	trolleybus	•	•	•	•			
	Gorzów Wlkp.	tramway		•		•	•		Transport closed for approx. 3 years (2017-2020) - complete renovation of the infrastructure
	Grudziądz	tramway		•			•		
	Kraków	tramway	•	•	•	•			
	Lublin	trolleybus	•	•	•	•			
	Łódź agglomeration	tramway	•	•		•	•	•	
	Olsztyn	tramway	•		•	•			New system launched in 2015
	Poznań	tramway	•	•	•	•			
	Silesian-Zagłębie ag.	tramway		•		•	•	•	
	Toruń	tramway	•	•	•	•			
	Tychy	trolleybus	•	•	•	•			
	Szczecin	tramway	•	•	•	•			
	Warszawa	trolleybus	•	•	•	•			
	Wrocław	tramway	•	•	•	•			
Slovakia	Banská Bystrica	trolleybus		•		•			
	Bratislava	tramway	•	•	•	•			
		trolleybus	•	•	•	•			
	Košice	tramway		•		•			
		trolleybus		•			•		Trolleybus traffic has been suspended since 2015
	Prešov	trolleybus		•		•			
	Žilina	trolleybus		•		•			

Source: own elaboration.

The analysis covered the full population of all tramway and trolleybus networks in the Czech Republic, Poland and Slovakia. All of them included modernisation of the infrastructure. These were investments of a varied nature, sometimes covering only small fragments. Only two cities were not included in this element (tramway in Olsztyn and trolleybuses in Prague), as these systems were put into operation in the analysed period in 2011-2020. The spatial development of infrastructure (construction of new routes) concerned only 30 out of 46 systems, with the smallest share in Slovakia. The development of infrastructure also led to launching new connections, which was noted in a similar number of tramway and trolleybus systems. In the analysed period, the vast majority of cities purchased new trams and trolleybuses. The only exception was Grudziądz (trams) and Košice (trolleybuses). Closure of connections without launching new ones on a given route was observed in 5 tramway systems (Brno, Gorzów Wielkopolski, Grudziądz, Łódź agglomeration, Katowice-Zagłębie agglomeration) and 3 trolleybus ones – small sections in Chomutov and České Budějovice as well as complete suspension of transport in Košice. The permanent removal of the infrastructure concerned two systems in the Czech Republic and two in Poland. In Brno (trams) and Chomutov, these were marginal fragments of routes of negligible importance for transport, while the removal of infrastructure in the Łódź and Katowice-Zagłębie agglomerations concerned entire tramway routes.

In 2011-2020, urban electric transport in Czech, Polish and Slovak cities developed with similar dynamics. Slovak cities had a slightly smaller share, as their transport policy mostly concerned the maintenance and modernisation of the rolling stock (Goliszek, Połom, 2015). Large financial and material investments were mainly made by Polish cities with trolleybus transport and some cities with tramway systems.

4.5. Characteristics of the development policies for urban electric transport

In the analysed countries, four characteristic types of policies related to the functioning and development of urban electric transport can be distinguished:

1) *regress model*, when the method of managing public transport leads to a limitation in the operation of connections serviced by electric vehicles. Insufficient funding leads to the degradation of infrastructure and rolling stock, contributing to the suspension or closure of part or all of the system. Such a model included, for example, the situation of trolleybus transport in Poland at the turn of the 20th and 21st centuries, as well as in recent years the tramway networks in Grudziądz, Gorzów Wielkopolski, the Katowice-Zagłębie agglomeration and the Łódź agglomeration. Today, Košice in Slovakia is an example of a policy aimed at eliminating trolleybus transport, as connections have been suspended since 2015 due to the wear and tear of vehicles. The tramway network in the Łódź agglomeration in Poland can also be partially included in the regression model;
2) *stagnation model*, when the level of financing is sufficient to maintain transport and ongoing renovation of infrastructure and rolling stock. Due to the lack of sufficiently high financing, it is impossible to restore assets, in particular to purchase modern vehicles, which makes it impossible to build competitive advantage of public transport over individual one. Part of the tramway systems in the analysed countries can be included in the stagnation model (e.g. in Elbląg, Grudziądz, Most a Litvinov, the Katowice-Zagłębie agglomeration, the Łódź agglomeration).
3) *moderate development model*, related to outlays exceeding current maintenance and offering a possibility of slight development, e.g. by building fragments of new routes or purchasing modern rolling stock. Examples of such a policy include tramway systems in Bratislava, Liberec, Olomouc, Ostrava, Toruń, Szczecin, Wrocław, as well as trolleybus systems in Chomutov, České Budějovice, Jihlava, Mariánské Lázně, Opava, Plzeň, Prešov, Ústí nad Labem and Žilina.
4) *dynamic development model*, characteristic of cities that have made urban transport the most important element of the development policy, recognising that only low-emission, accessible and comfortable public transport can improve the residents' living conditions. The model of dynamic development is associated with high expenditures on the functioning as well as infrastructure and rolling stock investments, often at the expense of other spheres of the city's functioning. Examples of cities that conduct their own transport policy in this way include tramway systems in Brno, Bydgoszcz, Częstochowa, Gdańsk, Gorzów Wielkopolski, Kraków, Olsztyn, Poznań, Warsaw, as well as trolleybus systems in Banská Bystrica, Bratislava, Brno, Gdynia, Hradec Králové, Lublin, Ostrava, Pardubice, Plzeň, Prague, Teplice, Tychy, as well as Zlín a Otrokovice.

The project to build a trolleybus system in Prague is an example that requires more extensive discussion (Bartłomiejczyk, Połom, 2019). Due to the size and importance of the city, the actions taken by the authorities of the Czech capital may be of key importance for future initiatives in other cities. Nowadays, Prague has an integrated system of public transport, which includes diesel and electric buses, trams, metro and

city rail. The system of trolleybus transport existed in 1936-1972. The Prague trolleybus network had the greatest range in 1959, and was gradually closed down in the following years. Trolleybuses were replaced with diesel buses. The aging rolling stock, the worn out traction and the power supply system were important arguments against maintaining trolleybus services. Ultimately, the fate of trolleybuses in Prague was determined by low crude oil prices at the turn of the 1960s and the 1970s. Plans to restore trolleybuses in Prague appeared as early as in 1981, and then in the mid-1980s. The most advanced works were at the turn of the 1980s and 1990s. Due to the deteriorating economic conditions after the political transformation and the breakdown of Czechoslovakia, the plans were suspended. Trolleybus transport in Prague was resumed in 2017, when a short test route was launched in October (Bartłomiejczyk, Połom, 2019). The topographic conditions of the city favour solutions based on electric vehicles, but due to congestion and large differences in elevation, electric buses did not pass the exam. Therefore, an attempt was made to introduce trolleybuses into operation. The operation of the trial route enabled assessing the possibilities of using trolleybuses in Prague. The tests were successful, which in turn led to the adoption of a staged plan of putting trolleybuses into service (Hinčica, 2019; Hinčica, 2020a), and later to the development of the concept and the possibility of operating suburban routes (Sůra, 2021). Actions taken by the Prague authorities are of key importance for the perception of trolleybus transport. On the one hand, they refer to the idea of other large centres, e.g. Berlin, which is running a similar project; on the other hand, they clearly emphasise that electric buses, easily implemented for public transport, are not always the best and optimal solution.

Equally important actions are taken by the authorities of Bratislava, which is also characterised by large differences in elevation. The public transport development policy assumes the modernisation and development of trolleybus connections. Similarly to Prague, it was necessary to purchase bi-articulated trolleybuses. Therefore, a Solaris Trollino 24 (Hinčica, 2020b) trolleybus produced in Poland was tested on the streets of Bratislava. Until now, such large-capacity vehicles have not been operated in East-Central Europe. They were typical of trolleybus transport in Switzerland and of the BRT systems.

Among other examples of the dynamic development of zero-emission transport there is the trolleybus system in Gdynia and Sopot. Currently, it is set as an example to be followed. Since the 2010s, efforts have been made to modernise the rolling stock, which was losing competition to low-floor buses. An innovative solution to convert low-floor diesel buses, purchased from the secondary market, into trolleybuses (using drives from the scrapped vehicles) resulted in over 30 vehicles that more closely corresponded to the modern requirements of the inhabitants (Połom, 2019). Moreover, the city of Gdynia used every opportunity to obtain external funds for the modernisation and expansion of the trolleybus traction infrastructure as well as the purchase of new vehicles. Between 2004, when Poland became a member of the European Union, and 2020, the number of trolleybuses increased from 75 to 104, and the number of transport tasks in peak times from 64 to 89. In addition, eight trolleybus lines use vehicles with an autonomous power source, which allows extending the line with sections without traction network, which is a record result in this part of Europe (Połom, 2018; 2019).

5. Conclusions

The article analyses the conditions for the functioning and development of urban electric transport in the Czech Republic, Poland and Slovakia. The comparative study on the diversity of transport policies in three countries in the East-Central Europe is the first one in the field of development of electromobility, and simultaneously all the more valuable as it concerns countries with a similar socio-economic history. An attempt was made to answer four research questions that concerned the level of development of tramway and trolleybus transport, system differences in their development, as well as technological impact on popularisation of emission-free public transport. The question of competitiveness of electric buses and the impact of their implementation on traditional means of public transport was an important research issue.

As a result of the conducted analysis, it was found that tramway and trolleybus transport developed more dynamically in Czechoslovakia, and then after division of the country in the Czech Republic and Slovakia, than in Poland. Despite the economic collapse after 1989, both countries continued the process of developing traditional means of electric public transport, while in Poland a period of strong regression began, which led to shutting down of 3 trolleybus systems and limitations in the operation of tramways. In later years, Polish cities undertook vigorous modernisation and investment activities, whereas in the Czech Republic and, in particular, in Slovakia the dynamics of activities was much slower. Nowadays, the level of investment is comparable; weaker and stronger centres can be identified in each of the analysed countries. However, the activities carried out in Bratislava and Prague deserve special attention, as significant development of trolleybus transport is planned there, which may provide an impulse for other cities. The

Czech capital, where trolleybus transport has been introduced from scratch (since 2017) after almost 50 years, is a special case. In Poland, there are no plans to build new tramway and trolleybus systems that would have realistic chances of implementation.

Several system and organisational differences that could affect the functioning of tramway and trolleybus transport have been identified. In particular, the strong position of rolling stock producers in Czechoslovakia supported the functioning of public transport. The Škoda and Tatra factories supplied trams and trolleybuses to Czechoslovak cities, but they were also the most important manufacturers of these vehicles within the Council for Mutual Economic Assistance. During the communist period, there was no independent producer of trolleybuses in Poland, so the position of trolleybus transport was not very strong due to problems with the supply of vehicles. As a consequence, trolleybus transport was not very popular, and today only three systems have remained that still suffer consequences from the past. The effect of the low importance of trolleybus transport in Poland can be observed in the prepared projects to support the purchase of vehicles for urban transport, where the trolleybus company is excluded from a possibility to lodge an application.

Modern technological development leads to the popularisation of means of transport powered by electricity. The possibility of installing on-board power sources (batteries) allows the trolleybus transport to be independent of traction power or to create new connections in places where there is no traction infrastructure or no possibility build it. On-board batteries can also become an important element of the tram's equipment, thanks to which they can leave the route on their own in emergency situations. The advantage of the battery has been used by manufacturers, and nowadays electric buses are relatively easy to put into operation. Quite easy implementation of electric buses leads to the popularity of zero-emission transport also in smaller towns, but at the same time they become competition to traditional trolleybuses. Ease of purchase does not go hand in hand with future operating costs, which are often not taken into account, and this can lead to regress in public transport.

Most of the analysed cities took advantage of development opportunities thanks to EU funds and government programs. Tramway and trolleybus transport in the analysed countries went from regression or stagnation to dynamic development. The conducted investment programs, in particular in Prague, may contribute to further studies on the legitimacy of the development of urban electric transport and competition between trolleybus transport and electric buses.

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