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The development of low-emission public urban transport in Poland

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Abstract. The aim of the paper is to identify the main factors and mechanisms behind the development of low-emission public transport vehicles in Polish cities. This innovation is primarily connected with growing environmental requirements for transport, with the EU environmental and transport policies being the key factors. However, strategies of local governments and municipal transport companies as well as the organization of urban transport - which differs significantly between cities - also play an important role. Three basic types of approach towards low-emission buses can be observed in Polish cities: tests of electric and hybrid vehicles, purchases of small quantities of buses in order to implement new solutions, and finally attempts to replace the majority or even the entire transport fleet with low-emission vehicles. It should be emphasised that an important element which affects the development of low emission public urban transport in Poland is the fact that the country has become one of the main bus producers in Europe - a fact which is a result of both large-scale foreign investments and the success of Polish manufacturers.

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1. Introduction

Currently, Polish cities are facing new challenges which are related to several different phenomena, including dynamic changes in spatial, demographic and social structures of their areas, increasing congestion and growing dependence on private motorization. An element which seems to be particularly important is the issue of the environment, especially the high level of air pollution in practically all cities of the country. One of the important sources of emission is transport, and its role in particulate matter emissions is increasing (Bokwa, 2008).

Undoubtedly, the development of public urban transport is a correct answer to increasing environmental problems. It may be considered as a part of the sustainable mobility agenda (Banister, 2008). However, the means of public transport themselves are also under growing environmental pressure, especially in city centres or in other zones of particular importance (e.g. tourist or spa resorts). Certainly, rail-based urban transport is the greenest solution; however, due to construction and operating costs, as well as high passenger numbers necessary for such a system to be economically feasible it cannot be introduced everywhere. For this reason, bus systems can be considered as lower-cost alternatives for corridors with low flows (Edwards, Mackett, 1996). Similarly, trolleybuses cannot be introduced everywhere. An interesting alternative is represented by low-emission buses using electric and hybrid technologies. In the last few years, the first vehicles of this type have been introduced by some Polish public urban transport companies. Considerable purchases of electric and hybrid buses for some towns and cities have already taken place or are planned in the near future. First projects to replace the entire fleet with electric vehicles have appeared as well.

The aim of the paper is to identify the main factors and mechanisms behind the development of low-emission public urban transport in Polish cities under growing environmental requirements. The main question which arises here concerns the actual decision-making process leading to the purchase of electric and hybrid urban buses. The complicated relations between transport organisers and suppliers as well as local governments and bus manufacturers form a certain framework for the development of this important innovation. The distribution of low emission vehicles in Polish cities which is the result of these relations is another crucial matter discussed in this paper.

2. Materials and research methods

The research methods applied herein can be divided into two main groups: the analysis of literature and available sources of data about the public urban transport in Poland, and interviews with decision-makers.

The analysed literature included studies of present trends in urban public transport development in the context of environmental requirements, with examples from different cities from around the world (Black, 1996; Rietveld, Stough, 2007; Gilbert, Perl, 2010). In order to collect information about the present situation of the low-emission bus fleet in Polish cities, the authors analysed data from municipal transport companies and the Central Statistical Office of Poland, as well as articles in trade and technical press and webpages of transport companies and organisers.

The second research method took the form of interviews with the decision-makers responsible for the development of low-emission public urban transport. The authors interviewed municipal transport companies' managers from three cities which invest in low-emission urban buses - Kraków, Jaworzno and Tarnowskie Góry and managers from main bus manufacturers present in Poland -MAN, Solaris and Volvo. In the case of the former the semi-structured interviews included questions about motivation behind the purchase of low-emission buses, the perception of this means of transport by municipal transport companies and plans for future extension of electric/hybrid bus lines. Similarly, the managers of bus manufacturers were asked about the factors which drove them to enter the electric/hybrid bus market and about future plans in the context of cooperation with public urban transport companies in Poland.

3. Background

Undoubtedly, transport is one the most important factors of the economic, social and spatial development of urban areas. However, at the end of the 20th century the belief in the desirability of perpetual growth in mobility started to fade (Greene, Wegener, 1997). This is because the current transport system - based mainly on private car - has demonstrated numerous limits and negative consequences, such as air pollution, traffic noise, partition or destruction of neighbourhoods, declining city centres, urban sprawl, congestion and accidents (Greene, Wegener, 1997; Banister, 2008). A particularly critical effect is the diverse and large-scale environmental impact of transport (Gudmunsson, Höjer, 1996). That is why the concept of sustainable development has been adopted to transport. Black (1996) defines sustainable transport as 'satisfying current transport and mobility needs without compromising the ability of future generations to meet these needs'. However, Goldman and Gorham (2006) argue that due to its complex character transport sector 'has proven to be a particularly difficult territory for the advancement of sustainable development policy'. In fact, to apply this idea to the present transport systems - especially in urban areas - seems to be the crucial challenge for the future transport development.

There are numerous ways of implementing sustainable transport strategies in cities. One of the most important is providing competitive alternatives to the private automobile - a strategy which Goldman and Gorham (2006) call 'new mobility'. A crucial context of this discussion is the general comeback to public transport: a tendency which can be observed especially in urban areas (Beirão, Sarsfield Cabral, 2007). Improving public transport is one of the measures which are implemented in order to decrease the demand for car use and to promote sustainable transport (Gärling, Schuitema, 2007). However, in order to fulfil these expectations public urban transport should be attractive, appealing and environmentally friendly itself. One of the instruments which can be used in order to achieve it is low-emission bus technology.

Certainly, the main factor behind the purchase of low-emission public urban transport vehicles is a new approach to environmental questions, in particular in urban areas. Due to the growing environmental problems - in particular air pollution and noise - the tendency to set limits on carbon dioxide emission gains importance. According to the European Commission (2016), transport is responsible for around a quarter of EU greenhouse gas emissions, making it the second biggest greenhouse gas emitting sector after energy production. Road transport alone contributes to about one-fifth of the EU's total emissions of carbon dioxide (http://ec.europa.eu/clima/policies/transport/index_en.htm, 2016). That is why the „decarbonisation" approach is clearly formulated in the European Union environmental policy and its carbon emission regulations (e.g., EC No 443/2009 and EC No 510/2011) which stipulate the objective of a 30% reduction of greenhouse gas emission by 2020.

However, the tendency to set limits on the role of traditional diesel technologies in transport is caused not only by the new attitude towards environment, but also by the need to decrease the dependence on fossil fuels, whose availability in the future is uncertain (Grenier, Page, 2012). The energy challenge will be forcing decision-makers to search for new solutions, and the most likely replacement for oil is electricity (Gilbert, Perl, 2010).

These factors form a framework for low-emission transport development. Environmentally-friendly technologies are being developed and improved. However, this is not a completely new phenomenon, in particular in municipal transport. In fact, the first means of mass urban transport was a fully zero-emission electric tram (1), introduced at the end of the 19th century (Taczanowski, 2016). Despite its disappearance from many Western European and North American cities between the 1930s and the 1970s, its role in Central and Eastern Europe - including Poland - has been basically maintained, at least in big cities (even though some lines and systems were closed down also in this region) (Kołoś, 2006; Taczanowski, 2015). By contrast, trolleybus - another zero-emission means of municipal transport which gained popularity especially in the 1940s and 1950s - has never been introduced on a large scale in Poland, unlike in many other Central and Eastern European countries, e.g., in the Czech Republic or Slovakia (Klas, Kohout, 2011; Podivín, 2011) (2). Notwithstanding, the existing trolleybus systems demonstrate that it can be an effective alternative, in particular for medium-sized cities, e.g., Gdynia (Połom, Palmowski, 2009). The existence of these alternative means of ecologic public transport in over 30 Polish towns and cities can be treated as one of the factors of low-emission bus technology development. It should be emphasized, however, that the latter technology is still at an initial stage and it is not clear which one is going to become predominant in municipal transport. Both hybrid (series and parallel) and electric powertrains have several advantages and drawbacks (Gajdowicz, 2010). The diversification in alternative powertrain technology increases the challenges in decision making; that is why it is necessary to study in great detail the different configurations of city buses (Lajunen, 2014).

4. Research results

4.1. Municipal transport in Poland and its organization

Municipal transport systems in Poland operate in about 260 cities and towns with a total population of circa 18 million. The total number of urban buses in Poland in 2015 amounted to 11,795 whereas the fleet of alternative fuel vehicles comprised 419 units (GUS, 2016).

Municipal transport in Poland is organized according to EU guidelines on separation between transport organizer and provider. However, different approaches of communes (Polish: *gmina*) - which according to the Local Government Act (*Ustawa o samorządzie terytorialnym*) and the Public Transport Act (*Ustawa o transporcie publicznym*) are responsible for public transport on their respective territories - can be observed in practice.

Four models of the organization of public urban transport market can be identified according to the criteria for the separation of regulatory and operational functions and the level of demonopolisation:

A. Dominant operator (with monopolistic position);

B. Dominant operator (with monopolistic position) controlled by the transport organizer;

C. Competition regulated by the transport organizer, i.e. competition for the market;

D. Deregulation of urban transport.

In practice, as public urban transport organization in Poland complies with the regulations that impose a separate transport organizer, model A does not exists and model D is limited to smaller towns. Consequently, models B and C are predominant.

However, communes comply with these regulations in two different ways. In the first case the commune is directly the transport organizer that commissions all transport services to its own provider without tender. This situation applies to model B and can be observed, e.g., in Łódź. *De iure*, this model is in line with EU regulation although *de facto* it enables to maintain the monopolistic position of municipal transport companies. In the other case - which applies to model C - the commune commissions the organization of urban transport to its specialized department or to a transport company. Two solutions can be identified here:

Transport market exists partially as both commune-owned and external companies are present and tenders for transport services are organized. However, it applies only to some selected services whereas most of them are still commissioned to the

internal commune-owned supplier, e.g., in Kraków or Warsaw.

The second case can be described as free competition as the public transport organizer commissions all local public transport services to external companies via a public tender, e.g., in the Katowice metropolitan area and in Wałbrzych in Lower Silesia.

4.2. Conditions for quality changes in the urban public transport fleet in the process of developing low-emission transport

Changes in the quality of public transport in Polish cities connected with low-emission bus development are a result of political, economic, organizational, social and technological factors, which may jointly be described as the institutional framework (Rietveld, Stough, 2007). Certainly, the framework underpinning decisions to purchase low-emission vehicles (LEVs) comprises EU environmental and transport policies. However, local environmental strategies and the perception of the need to introduce the so-called environmental zones in cities in order to limit air pollution are important as well. The town of Inowrocław is a good example: its local authorities strongly emphasize the need to place limits on air pollution and noise as one of the town's most important functions is being a spa resort (Chronmyklimat.pl 2015). On the other hand, public transport organizers and suppliers aim to reduce the operating costs of public transport, although in the same time the need to renew the fleet is often voiced. The decision-makers realize, however, that EU grants they may plan to apply for clearly prefer environmentally friendly technological solutions and that stricter environmental regulations are about to be introduced in the near future. Nevertheless, the tendency to invest in public urban transport also has an important social background as the decision-makers realize that there is a need to improve the image of public transport. Undoubtedly, the perceptions and opinions of the managers play a vital role here. Some of them declare that they see no other option for the future than to invest in low-emission technologies. The mechanism of LEV purchase in Poland is presented in Fig. 1.

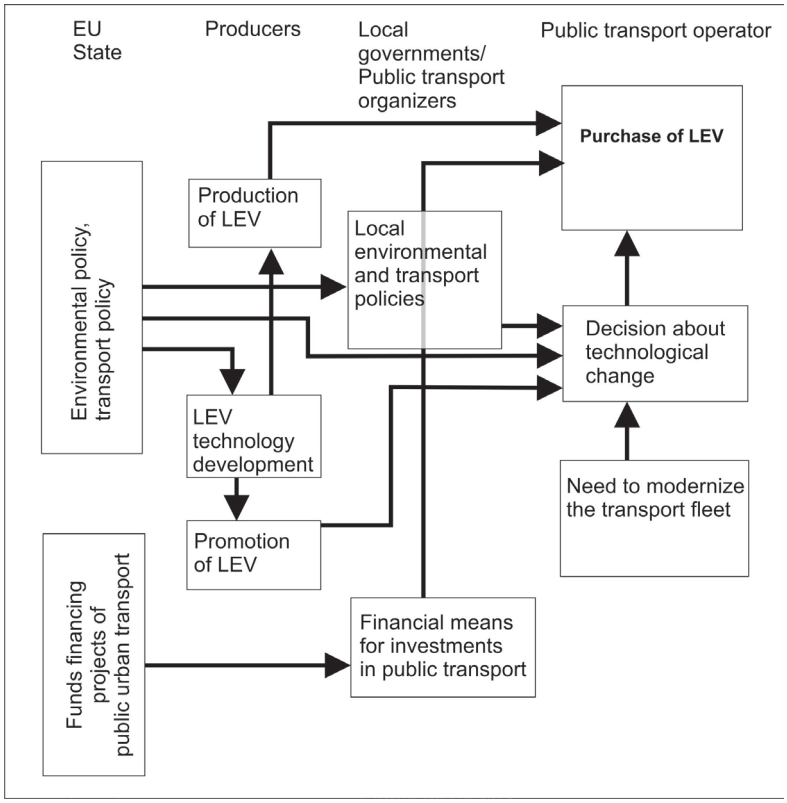

Fig. 1. The mechanism of low-emission vehicles' (LEV) purchase in Poland
Source: Authors' own elaboration

The pace of LEV adoption in Polish cities may be accelerated by the recent central government's policy as electromobility is a flagship project under Minister M. Morawiecki's national economic plan. In 2017, the National Research and Development Centre (the NCBR) launched an ambitious programme to speed up the electromobility in public transport (NCBR 2017).

The role of technological factors is undoubtedly crucial. In fact, low-emission technologies for municipal buses are still at an initial stage as many problems have not found a satisfactory answer yet. It applies to several important questions including the range of electric buses, the life cycle of the batteries, compatibility between infrastructure for recharging batteries, and the facilities in buses of different manufacturers and owners. Consequently, the diffusion of low-emission buses in Poland is partially an experiment whose results should enable decision-makers to learn which solution is the best and most suitable one. However, it should be emphasized that every city and its bus network is particular and individual solutions should be adapted in each case for many technical and operational reasons (length of the line, gradient of the road, frequency of stops, congestion on the road, average number of passengers).

Finally, an important factor of LEV development in Poland is the fact that the country is now one of the main bus manufacturers in Europe, both because of foreign investments (Volvo, Scania) and the rise of a Polish company (Solaris) followed by smaller producers like: Scania, Capena, Autosan, AMZ and recently Ursus (Gwosdz et al., 2011; Domański et. al, 2016). It would seem that the existence of innovative bus manufacturers who offer LEVs may foster the adoption of electric and hybrid buses in Poland. What is more, this relation seems to exist at the local scale as well. This is because thanks to geographical proximity it is easier for the producers to learn about the local market and to answer to its demands (e.g., while servicing the vehicles). Moreover, geographical proximity facilitates the demonstration of effects and knowledge flows. However, it should be emphasized that when local producers are leaders in the introduction of innovations, the danger of negative effects connected with privileges obtained by a local supplier - a tendency which is quite common despite transparency and non-discrimination standards - is significantly lower (Uyarra, Flanagan, 2010). The relation between the location of the bus manufacturer in a given city (or its metropolitan area) and the structure of the bus fleet of its main municipal transport company is self-evident (Table 1).

Table 1. The structure of bus fleets in municipal transport companies in selected Polish cities according to the location of bus manufacturers in 2015–2016

City	The share of manufacturers located in the Poznań metropolitan area in the entire bus fleet of the main transport company [%]	The share of manufacturers located in the Wrocław metropolitan area in the entire bus fleet of the main transport company [%]	The share of manufacturers located in Słupsk in the entire bus fleet of the main transport company [%]	The share of other manufacturers [%]
Wrocław	16.1[a]	55.5	0.0	29.0
Poznań	96.1	2.3	0.6	0.9
Słupsk	5.0[b]	0.0	78.0[b]	12.0[b]
Kraków	51.2	32.2	8.6	8.0
Warsaw	79.7	6.2	0.0	14.1

[a] almost all (57 z 58) of the 16% are Solaris buses which were purchased in 2014; since 2015, Volvo has been producing hybrid buses only
[b] data partially from secondary sources
Source: Authors' own elaboration based on the data of transport companies

4.3. Spatial distribution of hybrid and electric buses in Poland

The first Polish city to purchase hybrid buses was Poznań in 2008 (www.mpk.poznan.pl, 2016). Already in 2015, Jaworzno and Ostrołęka decided to invest in first fully electric vehicles. A year before, the first regular bus line operated by three electric buses was inaugurated in Kraków; however, at the beginning the vehicles were leased by the city's municipal transport company (MPK Kraków, 2014).

In November 2016, there were 96 hybrid buses in service in 14 cities (of which in one, Wrocław, the vehicle was rented by the municipal transport company) and 23 fully electric buses in 5 cities (of which in one, Kraków, 3 (of 8) vehicles were rented by the municipal transport company) (Fig. 2). Currently (as of November 2017), there are 142 hybrid buses in service in 18 cities (of which in one, Wrocław, the vehicle is rented by the municipal transport company) and 78 fully electric buses in 7 cities (of which in three, Warszawa, Krakow and Polkowice, some vehicles are rented) (Fig. 2A). At present (as of November 2017), successive buses: 57 hybrid and 93 electric, are being produced (of which 47 for one town, Zielona Góra). After all of them will have been delivered in 2018, the total amount of LEV in Poland will amount to 199 hybrid and 170 electric buses (Fig. 2B).

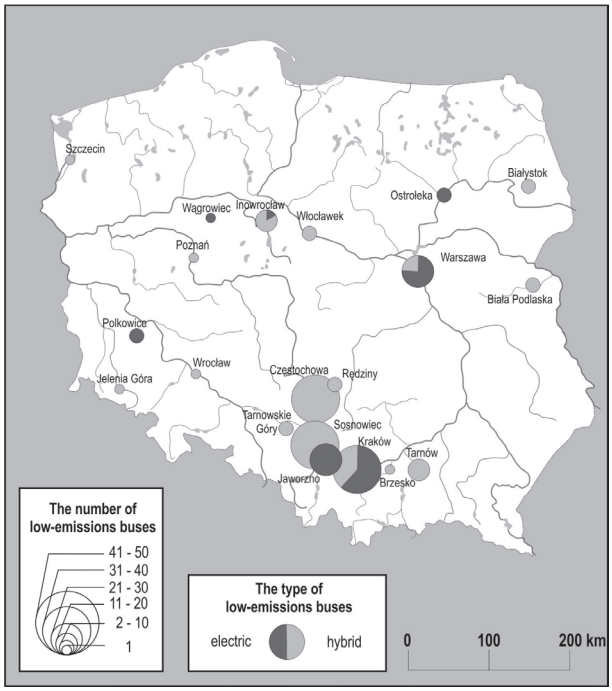

Fig. 2A. Low-emissions buses used in public urban transport in Poland (November 2017)
Source: Authors' own elaboration

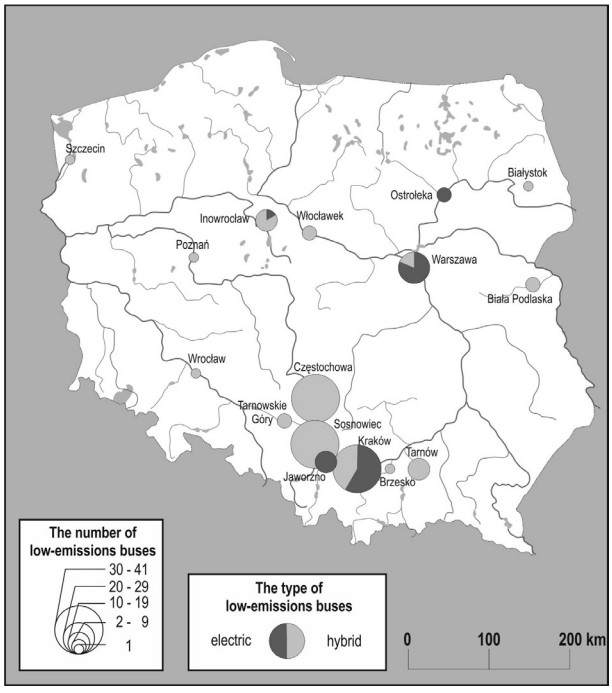

Fig. 2. Low-emissions buses used in public urban transport in Poland (November 2016)
Source: Domański et. al, 2016 (updated)

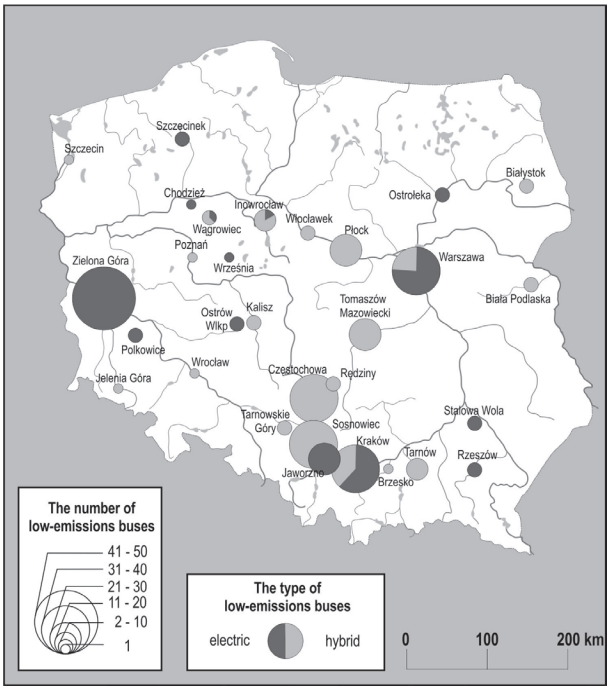

Fig. 2B. Low-emissions buses used and purchased in public urban transport in Poland (November 2017)
Source: Authors' own elaboration

The spatial distribution of the cities in which low-emission municipal buses are in service is interesting. In fact, two zones can be identified: southern Poland (with Kraków, Częstochowa, Tarnów, the Katowice urban area and towns in Lower Silesia) and central part of the country (with Warsaw, Włocławek, Inowrocław and Ostrołęka). In terms of the number of LEVs, the role of the former region is particularly significant.

It is worth noting that the leaders in LEV introduction are medium-sized towns with a population between 50,000 and 250,000. In fact, in Częstochowa the 40 planned CNG hybrid buses will constitute 30% of the entire bus fleet, in Inowrocław two electric and ten hybrid vehicles make up about 1/3 of the bus fleet and 30% of urban buses in Jaworzno are going to be fully electric in 2017 (*Nowe autobusy hybrydowe w Częstochowie…*, 2016; *Wkrótce co trzeci autobus…*, 2016; *W Inowrocławiu…*, 2016). The most ambitious plans to replace the entire bus fleet with electric vehicles come from another medium-sized town, Zielona Góra (*Zielona Góra coraz bliżej elektrycznych autobusów*, 2015). What is more, small towns are also beginning to invest in LEV as well, e.g., Polkowice (22,500 inhabitants) or Wągrowiec (25,000).

However, it does not mean that the largest Polish cities are not active in terms of LEV introduction. In particular, Warsaw and Kraków are introducing electric and hybrid buses as well. Nevertheless, they seem to prefer a more careful strategy which consists in the purchase of rather smaller numbers of vehicles, at least as compared to the entire fleet. It should be emphasized that some Polish cities have decided to test electric and hybrid buses without buying any vehicle yet (e.g. Radom).

Still, it is also significant that some major Polish cities and metropolitan areas have not launched any LEV projects, with the Tricity (Gdańsk, Gdynia and Sopot), Łódź, Lublin and Katowice among them. It is characteristic that two of them already have efficient zero-emission transport systems - trolleybuses in Gdynia and Lublin, as well as the first metropolitan railway in Poland in the Tricity.

An important observation applies to the pace of LEV development. Between November 2016 and November 2017, the total number of electric buses increased by almost 300% and hybrid vehicles by about 50%, whereas the number of cities with LEVs grew from 16 to 20. The delivery of the already-purchased new vehicles will result in a further increase in these numbers.

It is worth considering whether and to what extent the introduction of LEVs is connected with the organizational model of public transport. It seems that cities in which the market is partially open and the municipal transport companies owned by city authorities hold a strong position have the most

Table 2. Relations between the size, the general character of a town and its public transport and LEV introduction

City size	Situation of public transport	Public transport development	LEV implementation	Examples
Large cities	– Partially open markets – Electric urban transport (tram, metro, suburban railway) already exists	Dynamic development	Tendency to replace about 20-30% of the bus fleet with LEVs	Kraków, Warsaw
	Other	Slow development	Single tests of LEVs or no LEV development	Łódź, Katowice
Medium-sized and small towns	Such that promote sustainable development strategies (spa resorts, decision-makers interested in technological changes)	Medium or Slow development	Large-scale LEV introduction (even 100% of the fleet)	Inowrocław, Jaworzno
	Other	Regress	No LEV implementation	Wałbrzych

Source: Authors' own elaboration

favourable conditions for electric and hybrid bus development. Warsaw and Kraków are the best examples of the above. By contrast, both monopolistic markets (e.g. Łódź and Wrocław), and totally free competition model cities (e.g. Katowice or Wałbrzych) provide examples of very modest or non-existent investments in LEVs.

It would seem that there is a connection between the size of a town, the situation of public transport and trends in its development (renewal of the fleet, introduction of new lines, intelligent transport systems, passenger information), as well as LEV implementation (Tab. 2).

The forerunners in terms of LEV implementation seem to be either large cities which already have experience in electric urban transport and whose transport markets are organized according to model C (see: Municipal transport in Poland and its organization) or medium-sized and small towns which implement sustainable transport strategies. It would seem that the factors which hinder LEV development are: the lack of interest in sustainable transport and in public transport in general, as well as the lack of any competition for the market (models B and D). The former depends on the local governments, urban transport organizers and suppliers (transport companies).

In fact, different strategies of decision-makers - local councils and managers of municipal transport companies - can be observed in terms of LEV purchase. Indeed, their opinions on hybrid buses, and on fully electric vehicles in particular, are rather diverse. These different attitudes and experiences of several municipal transport companies' managers were presented at the conference *Electromobility in Polish cities. Low-emission buses – current challenges* (Polish: *Elektromobilność w polskich miastach. Niskoemisyjne autobusy - aktualne wyzwania*) which took place on 26 October 2016 in the Centre for EU Transport Projects in Warsaw (http://cupt.gov.pl, 2016). Decision-makers from the Wrocław city council emphasized the lack of an electric bus offer which would be suitable for the city. According to them, the actual vehicles turned out to be more expensive, with higher energy consumption, shorter life cycle of the batteries and smaller range than it had been presented by the manufacturers. The solution which was proposed by the city concerned new tests in which the city would participate offering financial and organizational support. However, the producers were reluctant to conduct tests in the city centre and they demanded that all costs be covered by the city (Urbanowicz 2016).

Managers from Poznań were also rather sceptical in terms of electric buses and they were promoting a different strategy in order to set limits on carbon dioxide emission. They preferred to concentrate more on encouraging the local population to change from private to public transport which should be achieved by extending the tram and bus networks. They emphasized the high costs of electric vehicles which could not be covered by several small-scale bus operators from the Poznań metropolitan area. Poznań strategy in terms of electric buses is to wait for other cities to introduce and develop this technology in order to collect their experiences. By contrast, managers from the Warsaw bus transport company were more enthusiastic about electric buses. In fact, they were planning to purchase 130 electric buses and expand electric bus lines in several districts of the city. In order to present different strategies of decision-makers who have decided to invest in LEVs two cases studies have been selected: Jaworzno and Kraków.

4.4. Case studies: Jaworzno and Kraków

4.4.1. Jaworzno

Jaworzno, a medium-sized town (94,000 inhabitants) situated on the fringes of the Katowice metropolitan region, is the first town in Poland which decided to purchase a fully electric municipal bus in 2015. As it was mentioned above, Jaworzno is one of the Poland's leaders not only in terms of the time of the acquisition, but also in the quantity and share of electric buses in the entire fleet. Moreover, it should be emphasized that *de facto* it is also the only Polish city which has a consistent strategy for the implementation of electric buses.

In fact, the town's Plan for sustainable transport development (UM Jaworzno, 2013) highlights the need for low-emission urban transport (however, applying mainly to a designed tram system that seems to have been abandoned) and presents the advantages of a bus 'with a hybrid or electric powertrain'. What is more, the document emphasizes that

LEV tests which took place when the Plan was being prepared resulted from the interest of the municipal transport company.

According to the managers of the Jaworzno municipal transport company, the electric bus project has been launched in order to meet the requirements of the EU transport policy according to which in 2030 fifty percent of municipal bus fleet should have an electric or a natural gas powertrain whereas by 2050 this indicator is supposed to reach 100%. The managers emphasize that EU regulations have set investments priorities for their firm (Interview with the manager from Jaworzno's Municipal Transport Company).

However, the project is a result of several tests of different buses with alternative powertrains, which lasted for four years, and of positive experiences with the first electric bus which was purchased in 2015. The managers from the Jaworzno municipal transport company stress high reliability of electric buses and very good passenger opinions (Nosal, 2016).

In fact, the implementation of electric buses which in 2017 should make up 30% of Jaworzno's bus fleet is part of a complex investment program which consists in the construction of charging stations and other indispensable facilities for electric vehicles and improvements in ticketing (*Wkrótce co trzeci autobus*…, 2016).

The first positive results of the Jaworzno electric bus project are already visible. According to local statistics, the share of inhabitants who use public transport has grown over the last two years and municipal buses are perceived more often as an attractive alternative to a private car (Nosal, 2016).

4.4.2. Kraków

Poland's second largest city, Kraków (762,000 inhabitants), can be also described as one of the leaders in LEV implementation. This is because already in 2014, the city opened the first bus line served only by electric vehicles, albeit with the vehicles leased and not purchased yet. What is more, Kraków's electric bus fleet - including vehicles which have been purchased but not yet delivered - is now the largest in Poland (28 buses, three of which are leased).

For a substantial time, low-emission transport development was not an important issue according to official local government documents. In fact, in the Kraków Development Strategy (UM Kraków, 2005) this problem was not mentioned at all, whereas the city's Transport Policy from 2007 (UM Kraków, 2007) only recommended that the introduction of a more environmentally friendly bus fleet should be promoted. However, a plan to purchase a larger amount of LNG buses resulted in a failure due to problems with the manufacturing of vehicles of this particular type. The situation changed only in recent years. The first document which not only clearly stipulated that the public urban transport fleet should be replaced by low-emission vehicles, but also indicated that 150 electric or hybrid buses were to be purchased was the Low Emission Economy Plan (UMK Kraków, 2015). Similarly, the latest city's Transport Policy (UMK Kraków, 2016) states that it is necessary to introduce an electric and hybrid bus fleet that meets the highest emission standards. The new Kraków Development Strategy which is now being drafted (UM Kraków, 2017) clearly indicates that electric urban buses should be purchased for the city.

According to the managers from the Kraków's municipal transport company (MPK), the reasons behind the introduction of the first electric and hybrid buses are: environment conservation, inspiration from other cities which have decided to implement LEV, the chance to bring public transport to the so-called green zones, and finally the increasing pressure for low-emission transport down the First Ring Road which encircles the Old Town. The last two factors should be particularly highlighted, especially in the view of the cultural heritage of the city and its role in tourism. An important motivation behind LEV implementation in Kraków has also been the strong position of domestic bus manufacturers, which facilitates the contact between the municipal transport company and the producers (Interview with managers from Kraków's Municipal Transport Company).

Similar to Jaworzno, Kraków also run several tests of electric buses between the years 2013 and 2015. However, their scale was larger than in any other Polish city as in April 2014 the city inaugurated the first regular bus service in Poland which was operated by three electric vehicles. Line number 154, which connects the Prądnik Biały housing estate in the northern part of the city with the

main railway station situated on the edge of the Old Town, was chosen as it serves the city centre. The main result of these tests was the decision to purchase the first four electric vehicles. They were introduced in line 154 in September 2016 (Motoryzacja.wnp.pl, 2016). In the same time, a tender for 20 electric buses (three of which are planned to be articulated vehicles) was won by the same company - Solaris (*Solaris dostarczy…*, 2016).

However, the attitude towards electric buses in Kraków is significantly different from that in Jaworzno. The managers from MPK highlight that their fleet is still going to be based on diesel buses whereas electric vehicles are planned to constitute just a part of the fleet, about 30 vehicles for the moment. The most important reasons behind that are the high price of the vehicles and the electric energy they consume (the latter may result in the need to build new power stations), as well as the fact that electric bus technology is still being researched and hence some questions have not been answered yet. This is particularly crucial in view of the fact that buses are supposed to be in service for about 10–15 years and thus the investment should be planned very carefully. Hybrid buses, by contrast, are about 20–40% more expensive than traditional vehicles but their fuel consumption is circa 10–15% lower. However, their construction and service is complicated and this technology is also still being developed.

Therefore, although the scale of investment in LEVs in Kraków is rather large and the development can be described as dynamic, the share of electric buses in the entire fleet is still low. Moreover, it does not seem that this situation is going to change in the near future. In fact, the city is an example of a relatively careful strategy of LEV improvement. The first fully electric bus line is still a larger-scale experiment and the decision-makers in the city council and the municipal transport company do not seem to have any intention to replace traditional buses by electric vehicles on a larger scale so far.

5. Conclusions

Over the last few years, several Polish cities have decided to implement low-emission buses, i.e. electric and hybrid vehicles, in their transport systems. The main motivation behind this move is the increasing pressure on local governments and municipal transport companies to introduce environmentally-friendly means of public transport, in particular in city centres and green zones. Undoubtedly, EU environmental and transport policies form a framework for this technological change which is a crucial step towards a sustainable mobility paradigm.

The actual mechanism behind LEV development in Polish cities is formed by the relations between the local government, the municipal transport organiser and supplier(s). In general, the institutional environment together with the regulatory framework play the dominant role. The most important elements of these relations are the actual organisational model of urban transport, local environmental strategies and the need to place limits on air pollution and invest in new technological solutions as seen by the decision-makers. Certainly, the opinions and experiences of the public transport managers play a particularly important role. Undoubtedly, one of the crucial issues is finance. Both public transport organizers and suppliers aim to lower the operating costs of public transport but at the same time they identify the need to renew the bus fleet and make public transport more attractive for passengers.

Hence, significantly differing approaches to this challenge can be observed in Poland. The spatial distribution of cities which have introduced LEV is particularly interesting as two zones are noticeable: the southern and - to a lesser extent - central part of Poland. What is more, it is not the largest urban areas of the country, but rather medium-sized towns, which can be described as leaders in LEV implementation. Some of them, especially those that emphasise sustainable development strategies particularly strongly, are planning large-scale LEV implementation, in some cases even in order to replace the entire fleet with electric buses. Nevertheless, dynamic LEV development, albeit with the tendency to replace only about 20–30% of the bus fleet with LEVs, can also be observed also in some large cit-

ies. However, it applies only to those cities which have partially opened public transport markets, i.e. where there is some kind of competition between the commune-owned municipal transport company and external companies. Generally, it would seem that cities with a partially open market and a strong position of the municipal transport company owned by the city authorities have the most favourable conditions for LEV implementation. Other large cities have much more careful strategies which primarily promote tests of new vehicles, whereas most medium-sized towns are not active in LEV implementation. Interesting questions arise, calling for further research: can the observed development be interpreted in terms of spatial diffusion of innovation? What is the role of geographical proximity between the above-mentioned actors, especially between bus producers and pioneering cities?

Apart from the institutional and geographical dimensions, the technological sphere is an important factor behind LEV development. However, it should be emphasised that both electric and hybrid buses are still a rather new technological solution and, hence, many questions have not been answered so far. The most important problems concern the electric bus range, battery life, power supply, energy demands and costs in the long run. It cannot be stressed too much that electric vehicles are not versatile and they have to be designed for a particular bus line. Neither are hybrid buses a well-established technology, especially due to their complicated construction. Both technologies are still being developed and the role of Polish bus manufacturers here is crucial. Certainly, the strong position of the country as one of the main European bus producer is an important factor which facilitates the implementation of these modern technologies in Polish cities.

Therefore, it seems that in most cases electric and hybrid buses are an interesting solution for a certain part of urban transport, especially in city centres, green zones and spa districts. However, at least for the moment, large-scale substitution of the entire bus fleet in many Polish cities still seems unrealistic. The future will demonstrate whether and to what extent electric and hybrid vehicles can be seen as an answer to the transport needs of Polish cities under growing environmental pressure.

Notes

(1) It may be considered zero-emission as seen from the local perspective where a given transport system operates and electricity is produced elsewhere. It is to note, however, that the real emission level depends on the technology used in the energy plant.

(2) Trolleybuses operate in three Polish cities only: Lublin (pop. 341.0 thousand), Gdynia (pop. 248.0 thousand) and Tychy (pop. 129.0 thousand).

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