t. LXXV ■ nr 4/2023 ■ DOI 10.33226/1231-2037.2023.4.4

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Autonomous transport in Polish cities – perspectives for implementation[1]

Transport autonomiczny w polskich miastach – perspektywy realizacji

Abstract

Autonomous transport is one of the main trends in the development of urban mobility. In Poland, this area is relatively poorly studied, partly because of the small number of implemented projects. So, do autonomous vehicles have a chance to become more frequent sight on Polish streets? The authors of this publication have two objectives. The first is to assess plans and measures undertaken to implement autonomous transport in Polish cities. The second aim of the publication is to define further perspectives for the development of autonomous transport in Polish cities. The basis of the survey was formulated as the following research problems: What is the level of advancement of autonomous transport implementation in Polish cities? What is the interest by the authorities of Polish cities (local government units) in the subject of autonomous transport? The authors decided to use triangulation of studies. On the one hand, hard data were collected (by analysing the strategic documents of cities), on the other – a survey was conducted. The survey itself collected information about the measures implemented as well as more subjective and prognostic elements related to the "opinions" of Polish cities on autonomous transport. Activities for the implementation of autonomous transport in Polish cities are at a low level. The study shows that the road to autonomous vehicles in public transport in Polish cities is still a long way off: their experience in implementing such innovative projects is very scarce, mostly because benefits of implementing modern technologies in public transport are not really perceived, while a lot of organisational and financial barriers are obvious.

Keywords:
autonomous transport, sustainable transport, mobility, urban strategies

Streszczenie

Transport autonomiczny to jeden z głównych trendów rozwoju mobilności w miastach. W Polsce obszar ten jest stosunkowo słabo rozpoznany, po części ze względu na niewielką liczbę realizowanych projektów. Czy zatem pojazdy autonomiczne mają szansę stać się częstszym widokiem na polskich ulicach? Autorom przyświecają dwa cele. Pierwszym jest ocena planów i podjętych działań w zakresie wdrożenia transportu autonomicznego w polskich miastach, a drugim – określenie dalszych perspektyw rozwoju transportu autonomicznego w tych ośrodkach miejskich. Podstawą badania ankietowego był następujący problem badawczy: Jaki jest poziom zaawansowania wdrażania transportu autonomicznego w polskich miastach? Jakie jest zainteresowanie tematyką transportu autonomicznego ze strony władz polskich miast (jednostek samorządu terytorialnego)? Autorzy zdecydowali się na triangulację badań. Z jednej strony zebrano twarde dane (poprzez analizę dokumentów strategicznych miast), z drugiej przeprowadzono ankietę. Samo badanie pozwoliło pozyskać informacje o wdrożonych działaniach, jak i bardziej subiektywne i prognostyczne elementy związane z planami i przemyśleniami włodarzy polskich miast na temat transportu autonomicznego. Działania na rzecz wdrażania transportu autonomicznego w polskich miastach są na niskim poziomie. Z badania wynika, że droga do pojazdów autonomicznych w transporcie publicznym w polskich miastach jest jeszcze daleka. Doświadczenie we wdrażaniu innowacyjnych projektów i zainteresowanie tego typu projektami jest bardzo małe, głównie dlatego, że nie dostrzega się korzyści płynących z wdrażania nowoczesnych technologii w transporcie publicznym, natomiast widzi się wiele barier organizacyjnych i finansowych.

Słowa kluczowe:
transport autonomiczny, zrównoważony transport, mobilność, strategie miast

JEL: O32, Q56, P31, R42

Introduction

The development of public transport is multi-threaded. On the one hand, we are witnessing rapid development of alternative energy sources, whereas on the other – vehicles are increasingly moving in partially or fully automated mode. The aim of this publication was to examine the extent to which autonomous transport remains in the area of interest of Polish city authorities, as well as to assess the prospects for implementing autonomous transport systems. The research was inspired by projects carried out in European countries, as well as two projects implemented in Poland. With the increasing shortage of professional drivers, the topic also remains important in social terms – it is argued more and more often that, in addition to economic benefits, an important effect of the implementation of autonomous vehicles will allow to eliminate the shortage of specialists on the labour market.

The area of autonomous transport remains the current direction of research. This is evidenced by the number of publications on this subject. As an example, Springer database contains over 106,000 results for the entry "autonomous vehicles" (as of 13 January 2023), most of them are publications in the field of engineering (about 31,000) and IT (21,000). By far the largest part of these numbers are publications concerning the sub-discipline related to artificial intelligence (almost 31,000 publications). Many publications also concern related subdisciplines: computational intelligence (8,400) and computer networks (7,100) or mechatronics (8,500), as well as robotisation and automation (5,500 publications). In the Scopus database there are 16,919 publications for the entry "autonomous vehicles" (as of 13 January 2023), mostly in the field of engineering (12,675) and computer sciences (8,838). The interest of researchers in this area is consistently growing, resulting in a significant increase in the number of publications on autonomous transport in 2019–2021.

Literature review – autonomous transport

Works in the field of autonomous transport usually concern five aspects: technological, administrative (regulations and guidelines of governmental and non-governmental organizations), sociological, urban – impact on infrastructure, efficiency, including environmental impact.

It should be noted that the vast majority of publications concern technological aspects – the use of artificial intelligence, automation or communication techniques (e.g. Almlöf et al., 2022; Ushakov et al., 2022). The area of application of these technologies in transport, logistics and urban development remains much less explored. Narrowing the search in the Scopus database (as of 13 January 2023) to "autonomous vehicles" and "cities" shows just over two thousand publications, of which only 134 concern the area of management and finance, and 187 – environmental sciences.

Polish researchers, for example Choromański et al. (2020), address the subject by introducing their definition for an autonomous vehicle. According to this definition, an autonomous vehicle is one that has two basic properties: it moves independently (i.e. without any participation of the driver), and is able to cope intelligently on the road, performing the required manoeuvres. Such a definition, according to the authors themselves, does not have to be considered perfect – according to it, a rail vehicle that moves independently (because it does not perform manoeuvres) can be considered non-autonomous.

According to the SAE classification (also recognised in the USA by the National Highway Traffic Safety Administration), vehicles can be classified into six groups, their autonomy being ranked on a scale from 0 (no driving automation) to 5 (full driving automation). With each subsequent level the vehicle is gradually taken over by the control automation – on lower levels, the driver gradually gives up driving of the vehicle, but remains its supervisor. At level 3, the driver takes control of the vehicle only when necessary (when the vehicle needs support). At levels 4 and 5 automated driving features no longer require any control being manually taken over (NHTSA, n.d.; SAE, 2021a, 2021b). Currently, NHTSA indicates five levels of vehicle autonomy (similar to SAE), also indicating that after 2025 an era of automated vehicles will begin (NHTSA, n.d.). It should be observed that previously NHTSA has also developed its own four-level (+zero level) classification of vehicle autonomy (Neumann, 2018, p. 787–788). The SAE rating has become the industry standard.

One of the interesting areas addressed by researchers today is social acceptance for public transport systems based on autonomous vehicles (Menon, 2019; Yuen et al., 2022). To increase the public's acceptance of AVs, it is important to understand underlying factors that influence it. Some preliminary attempts have already been made in this respect. Based on a study by Zhang et al. (2019) to promote public's acceptance of AVs, related organisations should target on improving the trustworthiness of AVs. This can be achieved by reducing system flaws and incorporating safety

enhancement functions, given that perceived risks to safety were found to be negatively related to users' initial level of trust.

Another area of research is the impact of autonomous mobility on urban infrastructure and the costs of its construction, maintenance or use (Duvall, 2019; Manivasakan, 2021; Zhang & Guhathakurta, 2017). It is estimated that autonomous vehicles will reduce overall transport costs and improve mobility, influencing our behaviour as well as fees (e.g. for access to parking infrastructure). Thus, in modelling the traffic in terms of the impact of autonomous vehicles on transport in cities, additional elements should also be taken into account, regarding travel using different means of transport, shared vehicles, rates for access to infrastructure, etc. (Shafiei et al., 2021).

A separate issue is the assessment of the efficiency of the vehicles themselves (Lécureux & Kaddoura, 2021; Steck et al., 2018) and the environmental impact of the development of public transport systems (Huber et al., 2022, Silva et al., 2022). Autonomous vehicles enable reduction of fuel consumption, congestion and improve flow of traffic. Among the benefits related to the implementation of autonomous vehicles, the following are also indicated: less road accidents, reduced emission of pollutants, increased mobility (and thus the level of quality of life for people unable to drive vehicles), reduced levels of stress, and increased safety for cyclists (Pettigrew et al., 2018). Based on data collected from the operation of individual vehicles of this type, it is estimated that full traffic autonomy would reduce air pollution with carbon dioxide by 15%, and with nitrogen oxides by 73% (Stern et al., 2019). Besides, the advantages of implementing autonomous vehicles also include a reduction in the global number of vehicles moving in the cities, and the associated less pressure upon providing parking spaces (Hasan & Van Hentenryck, 2021).

Another interesting issue is that of responsibility for the operation of an autonomous vehicle. Various entities may be held responsible for damages resulting from their circulation in road traffic, including, potentially: the vehicle driver, vehicle owner, vehicle operator, vehicle manufacturer, software producer/author, as well as public authorities enacting the rules for the movement of such vehicles (Robaczyński, 2022, p. 69). The literature on the subject contains numerous publications on the liability of autonomous vehicles and related ethical issues (Hevelke & Nida-Rümelin, 2015; McManus & Rutchick, 2019; Li et al., 2016; Liu, 2017). The role of the city and its authorities, however, is not to define the legal framework, but only to plan the use of technology based on this framework.

Implementation of autonomous transport systems

The growing interest in autonomous vehicles results in the implementation of large, international pilot projects. The projects AVENUE, SHOW and Sohjoa Last Mile are worth mentioning in this context. Within the framework of the AVENUE, implemented in 2018–2022, it was assumed to create and put into operation automatic public transport vehicles in four European demonstrator cities (Geneva, Lyon, Copenhagen, Luxembourg), and later in three replicator cities. The idea of the project was very simple – to give passengers the ability to move from point A to point B using autonomous vehicles, in particular by targeting elderly people, people with disabilities and vulnerable users (AVENUE, n.d.). As part of the SHOW project (implementation between 2020 and 2024 with a budget of EUR 30 million), a total of at least 70 automated vehicles will be put into service: robotaxis, buses and shuttles, for both passenger and freight transport. These vehicles are and will operate at the 4th and 5th level of autonomy, using different routes (dedicated lanes and mixed traffic) and different speeds (from 18 km/h to over 50 km/h). The project is led by German, Swedish, French, Austrian and Spanish cities and involves a total of 70 partners from 13 EU countries. These include management organisations (including UITP), equipment and technology suppliers and public transport operators. In general, the project aims to show the possibilities of implementing sustainable urban transport in four areas: Public Transport (PT), Demand Responsive Transport (DRT), Mobility as a Service (MaaS) and Logistics as a Service (LaaS) based on real-life urban demon-strations all across Europe (SHOW, n.d. a; n.d. b; n.d. c). There are no partners from Poland in the AVENUE or SHOW projects.

The Sohjoa Last Mile programme, supported by Interreg Baltic Sea Region, remains one of the largest autonomous vehicle pilot projects in Central Europe. Since 2019, a large number of pilot projects related to autonomous vehicles have been carried out in Europe, usually funded by a variety of EU funds. One of the projects was Sohjoa Last Mile, which involves piloting autonomous vehicles in three cities: Kongsberg (Norway), Tallinn (Estonia) and Gdańsk (Poland). The aim of the project was to identify the possibility of operating vehicles without an operator on board. The pilot runs were carried out in both closed and open areas. And although the idea of pilot schemes in all cities was similar, the experiences were very different, depending on local conditions. Gdańsk is the first and only city in Poland to have carried out a pilot project related to autonomous vehicles. The vehicle was moving around the cemetery, and the pilot was already the

second such project in Gdańsk. Kongsberg tested an unmanned vehicle as part of an on-demand transport service to eliminate empty mileage and ensure energy efficiency – the first such project in Norway. In Tallinn, on the other hand, unmanned operations were carried out from day one, and the supervision of the traffic was also provided, with contribution from the University of Riga – which allowed to build competences related to the operation of autonomous vehicles in two countries simultaneously (Sohjoa Last Mile, 2021).

The free on-demand transport service has already been available in Kelheim (a town north of Munich, Germany) as part of the KEXI (Kelheim Express Individuell) project. Residents can book autonomous vehicles for journeys within the public transport system. From 2021, the on-demand transport service was available in conventional vehicles, and in 2022 it was joined by two autonomous EZ10 vehicles, operating from Monday to Friday from 9 AM to 4 PM. Autonomous vehicles run between the old town and the shopping district, on a network of roads with a total length of almost 14 km and speeds of up to 20 km/h (Easymile, 2022). Germany's autonomous transport projects also include a research project in Lower Saxony, where Alstom and its partners are conducting trials for driverless operation in rail transport, starting with automatic sign and signal recognition. Ultimately, this should lead to the deployment of autonomous vehicles in regional rail traffic (Alstom, 2022).

Methodology

In order to identify the advancement of the implementation of the concept of autonomous transport in the strategies and activities of cities, a survey was conducted in the form of an indirect, in-depth, standardized interview addressed to the local government authorities of 37 Polish cities with over 200,000 inhabitants. The research tool was a questionnaire consisting of 22 questions, divided into two parts. The first concerned autonomous transport in the city's strategy, the second related to the plans and prospects for the implementation of projects in the field of autonomous transport. This division is justified by the research plan, striving to obtain reliable answers excluding the respondent's fatigue. The survey had an online form with open and closed questions. The multiple-choice questions were mainly based on ranking (Runge, 2006). The time frame of the study covered the period from May to August 2022. The study was conducted in parallel with the analysis of strategic documents.

This was not the first attempt at this type of research. Originally, the authors planned to conduct this type of study in European cities (selecting cities with over 1 million inhabitants). Unfortunately, the response rate of these surveys was low, hence the decision was made to conduct the research more locally, in cities in Poland. The authors of the publication consider the topic to be extremely interesting and do not exclude the possibility of undertaking similar research in the future, also for other countries.

Autonomous transport in city strategies – analysis of strategic documents

As part of the research work, review of strategic documents was carried out. This section presents the results – a short commentary on selected documents, their content and directions of transport development.

Włocławek, in its City Development Strategy developed with goals until 2030 (*Strategia rozwoju miasta Włocławek*…, 2021), points out the importance of sustainable transport, with an emphasis on moving away from individual car transport to public, pedestrian and bicycle transport. According to the answers in the questionnaire, the city administration plans to introduce autonomous public transport after 2025. In the case of Włocławek, it is worth considering the possibility of implementing autonomous vehicles in a multimodal way. This is also reflected in the Strategy, which describes the growing importance of multimodal transport in the region, supporting transit traffic in the city and the inclusion of the railway and water network in the functioning of the city. Therefore, it gives the opportunity to develop autonomous transport in a comprehensive way, rather than, as most cities usually do, only focusing on one branch. A holistic approach gives an advantage, as industry partners will be able to easier develop the technology by working together in various transport modes.

Rzeszów local government has been planning to introduce autonomous vehicles in public transport for several years (*Strategia rozwoju miasta Rzeszowa*…, 2015). The first plans for autonomous vehicles in Rzeszów emerged in 2010. At that time, the idea which was not implemented, was related to the development of a surface railway on one "monorail". In 2019, the city authorities undertook efforts to implement an autonomous bus. A budget of PLN 3.4 million was prepared for this purpose and a route was defined. Initially, this type of vehicle would run between the Rzeszów PKP main railway station and the Local Railway Station at Towarnicki street, covering a distance of about one kilometre. Representatives of the city authorities,

using the principle of benchmarking, decided to go to the Dutch Rivium economic zone in Rotterdam to see how a driverless bus is used there. However, in 2020, the Rzeszów councillors adopted a resolution to freeze the project of purchasing autonomous buses, justifying their decision with the expenses related to the COVID-19 pandemic and the need to transfer funds to other current expenses of the city.

In its current development strategy until 2030 (*Strategia rozwoju miasta Płocka*…, 2018) Płock administration draws attention to the need to implement transport innovations, as the transport infrastructure serving Płock has not kept up with positive technological changes in the city itself. The city is planning to implement sustainable development of urban transport through the use of intelligent technologies, which in the future may be the seed for, for example, the implementation of autonomous solutions in urban traffic.

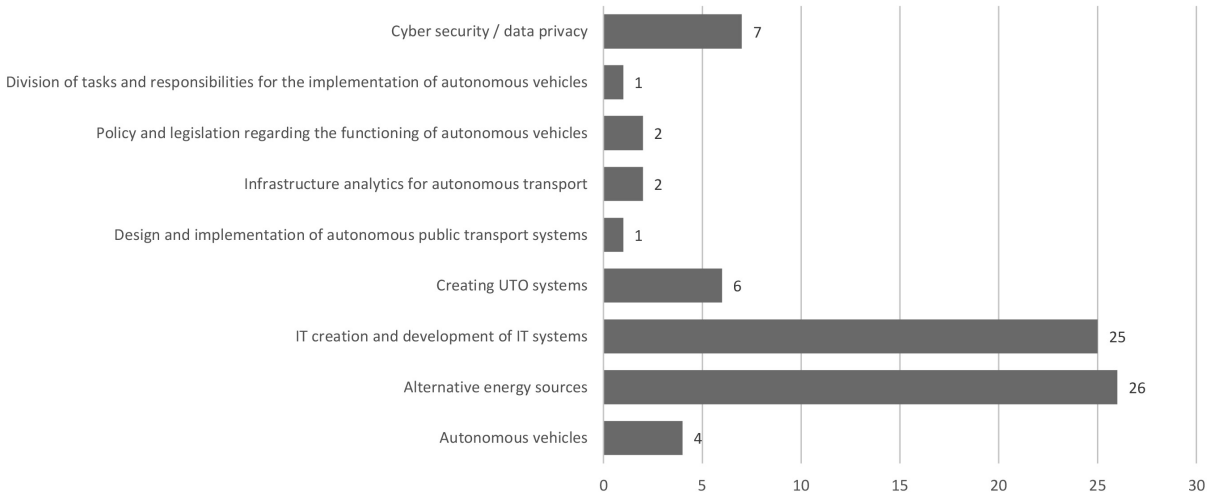
The Sustainable Mobility Plan for the Wrocław Functional Urban Area (*Plan zrównoważonej mobilności*…, 2022) is one of the first documents of this type in Poland, which holistically presents modern and ecological transport solutions for several dozen communes in total. The plan consists of two parts – operational, the implementation of which is scheduled for 2030, and strategic – until 2035[2]. The main assumption is to base communication on rail transport with transfer nodes, which is to be supplemented by bus transport. Other assumptions are to increase the importance of pedestrians and cyclists and, finally, to improve the access to transport for all inhabitants of the region. The study also includes the standards and policy of UTO and e-mobility regulation. The authors of the study point out that "the development of e-mobile means of transport will allow to reduce the environmental pressure of the transport sector. The directions of action include, for example, the development of electric vehicle charging stations and points, encouraging residents to use e-mobile means of transport, the development of bicycle rental systems (also with the use of electric bicycles) and UTO".

Autonomous transport in urban strategies – survey results

The first question concerned plans of the city authorities regarding the development of public transport based on autonomous vehicles in the near future. Only three cities are considering, in the near future, the development of urban transport based on vehicles that enable traffic without driver interference. The authorities of one of these cities declared in a survey that they would start work on introducing autonomous public transport by 2025.

Next question in the survey directly related to enacted transport development strategical documents. The cities surveyed have strategies for the development of public transport, 14 cities have strategies for the development of individual transport, only nine of them have strategies for the development of personal transport equipment (category of vehicles defined in Polish law as electrically driven – excluding electric scooters – without seats and pedals, structurally designed to be operated only by the driver on the vehicle). Six cities have developed a strategy for cargo transport. The cities surveyed also identified the thematic areas they address in their development strategies (Figure 1).

Figure 1
Transport-related elements included in city development strategies



Source: own studies.

Based on the responses received, only one city considers the potential impact of autonomous vehicles on urban development in its strategy. The transport organiser notes that autonomous transport generates many benefits for cities, mentioning, among others: "reducing the cost of maintaining public transport, both collective and on-demand services, increasing road safety, opportunities to significantly improve the urban environment, achieving a very high quality of mobility services and the possibility of effectively eliminating transport exclusion of people and areas".

Another of the survey questions related to documents already developed, at the national or regional level, defining the city's strategy in the area of autonomous transport. Respondents pointed to various documents, including the Sustainable Development Strategy of Transport to 2030 (*Strategia zrównoważonego rozwoju transportu*…, 2018) or the Smart Growth Operational Programme (Program operacyjny Inteligentny Rozwój – POIR). In the context of subsequent replies (e.g. on the financing of projects), the indication of the POIR is particularly interesting.

Autonomous transport – projects and implementation

A separate part of the survey was dedicated to autonomous transport projects and plans for their implementation. As many as 93.1% of respondents declare that their cities do not currently have plans related to the implementation of such projects. Individual affirmative responses were also obtained – in one of the cities, tasks related to the movement of autonomous vehicles in regular traffic are planned, in another – this is planned in a separate space (such as a cemetery or a fairground). The few planned projects will include both driving with passengers and supervising staff and driving with passengers without any staff or ongoing supervision.

In all questions regarding autonomous transport implementation projects, the projects were scored by "zero" or "one", i.e. they were treated as being (having been) implemented or not. Therefore, the degree of implementation of these projects or the intention to implement them was not assessed (on any scale).

When describing their plans for autonomous vehicles with answers to an open question, respondents indicated, among other things, the lack of funding for the implementation of such projects (justifying the implementation of the pilot by obtaining financial support from external sources). The declared interest in autonomous vehicles concerned small vehicles, usually designed to carry a few passengers. Within the framework of previous activities, cooperation with research centres (universities), both from Poland and abroad, as well as with research and research institutions other than universities, has been declared.

The main motives for the introduction of autonomous vehicles include technological progress, improved safety, improved energy efficiency, and the perception of the city as innovative. What is interesting, therefore, are motives related to technology and the development of public services as such, as well as elements related to building city marketing.

Although only a few urban centres identified autonomous mobility projects in their plans, a larger number of open answers were collected in the question on "potential implementations" and their area. This suggests that some cities, although they do not plan to launch autonomous public transport today, would see such vehicles on their streets in the longer term. Areas of "potential implementation" included the introduction of autonomous vehicles in the zone "without access to traffic by other means of transport" or as a "regular line in the Old Town area". In one of the cities, the potential of introducing autonomous vehicles in tram traction was taken into account, in another – the lack of decision-making power of the city in this area (due to analyses and implementations being done at the metropolitan level).

Vast majority of cities did not conduct surveys among its residents on their confidence in autonomous transport. To this question, 92.6% of respondents gave negative answers – not only no studies were actually caried out, but none were even planned. In one case, such studies were conducted, in another – while not having been carried out yet, at least they were planned. A little more involvement of cities can be seen in the area of routes and route planning for this type of vehicle. Here, 76% of respondents indicated that studies of potential routes had neither been carried out nor even planned, but already one in five respondents (20%) indicated that such studies were planned and in one city the studies had been carried out. None of the cities surveyed declared having infrastructure dedicated to electric vehicles (such as lanes dedicated for their exclusive use). Plans to create such infrastructure were confirmed in one city.

Due to the low interest of cities in autonomous transport technology, the authors of the study were more interested in analysing the answers to questions related to the limitations and barriers resulting from this type of implementation. Among the barriers, the lack of financial resources for

investments was by far the principal one. Technical factors played an important role in the group – respondents highly rated the barriers related to lack of knowledge or technological imperfection. Barriers related to inefficiency of autonomous transport (both in terms of low capacity and operating costs), organisational or psychological barriers, were given lower rank. Such an arrangement of respondents answers shows that although new technologies bring challenges, cities are not afraid of them – and a slight emphasis on mental limitations can be considered one of the good prospects for the future.

Autonomous transport – trends

Analysis of literature, strategic documents and survey results allows to identify several basic trends related to the implementation of autonomous transport and related barriers.

The development of autonomous vehicles is accompanied by the development of technologies related to artificial intelligence (AI), large data management and broadly understood telecommunications and ICT infrastructure. Urban mobility also means many integrations, as autonomous vehicles are meant to be part of a larger public transport system. Integrations, admittedly, that will increasingly refer to shared means of transport (it is worth mentioning, for example, slogans such as "sharing economy" or "micromobility").

In Polish reality, the main problem is the lack of financial resources that local governments could allocate for this type of investment. The year 2022 brought a discussion about the need to reduce investments due to the sharp decline in city revenues (related to changes in the calculation and settlement of PIT tax). Therefore, the main barrier for autonomous vehicles in public transport is not the lack of appropriate legislation or the fear of new technology, but rather an economic problem.

Conclusive remarks

Referring to the first objective of the article, it can be stated that the plans (documents) and activities for the implementation of autonomous transport in Polish cities are at a low level. The study shows that the road to autonomous vehicles in public transport in Polish cities is still a long way off. As the main conclusions of the conducted study, the authors state that:

- Polish cities have little experience in implementing innovative projects,
- there is very little interest in such projects, especially in the short term (for which specific plans and projects to be implemented can be defined),
- cities do not see the benefits of implementing modern technologies in public transport,
- the main barrier to the development of autonomous vehicle projects is the lack of financing mechanisms,
- the city authorities fear an increase in the debt of local governments as a result of the implementation of innovative projects and an increase in the current costs of their operation, in particular since any potential improper implementation may result in the need to return some or all of the subsidies for selected projects.

It seems that in the conclusion, on the basis of the considerations related to the second purpose of the publication, several recommendations for the city authorities can be formulated with a view to increasing the benefits of the development of innovation and the implementation of modern technologies. In Polish conditions, it would be worthwhile to consider finding external financing for projects related to autonomous vehicles. An example of such a solution may be the Horizon Europe program – as one of the optional solutions. Another solution could be the cooperation of local government units with non-governmental organizations. Close cooperation of local governments with technology companies may be one of the solutions for the digital and green transformation of public transport. Without it, the gap between the level of services provided by the public and private sectors will continue to widen.

The survey was conducted in 2022, after the COVID-19 pandemic (in the last two years, the funds of local government units were mainly allocated to fighting the pandemic) and after the outbreak of war in Ukraine, but before the peak of energy problems. The prospects for the poor financial condition of local governments, i.a. lack of funds for financing investments in cities in the coming years may additionally hinder the implementation of projects related to autonomous mobility. Therefore, the potential of implementing this type of vehicles in Polish cities should be carefully monitored, as in the current macroeconomic conditions the number of implemented projects may be even lower than declared by the respondents.

However, research in other cities are worth continuing, in order to make comparisons, further verify the results obtained, and try to collect a set of experiences in the field of implementing autonomous vehicles in public transport.

Notes/Przypisy

[1] The project financed within the Regional Initiative for Excellence Programme of the Minister of Education and Science of Poland, years 2019–2023, grant no. 004/RID/2018/19, financing 3,000,000 PLN.

[2] https://www.wroclaw.pl

References/Bibiografia

Almlöf, E., Nybacka, M., Pernestal, A., & Jenelius, E. (2022). Will leisure trips be more affected than work trips by autonomous technology? Modelling self-driving public transport and cars in Stockholm, Sweden. *Transportation Research Part A: Policy and Practice*, 165, 1–19. https://doi.org/10.1016/j.tra.2022.08.023

Alstom. (2022). *Digitalisation in regional passenger transport*. https://www.alstom.com/press-releases-news/2022/6/alstoms-pilot-project-autonomous-driving-germany-enters-next-phase (accessed 14.06.2022).

AVENUE (n.d.). *What is AVENUE project?* https://h2020-avenue.eu/summery/ (accessed 22.12.2022).

Choromański, W., Garbarek, I., Kozłowski, M., Czerepicki, A., & Marczuk, K. (2020). *Pojazdy autonomiczne i systemy transportu autonomicznego*. Wydawnictwo Naukowe PWN.

Duvall, T., Hannon, E., Katseff, J., Safran, B., & Wallace, T. (2019). *A new look at autonomous-vehicle infrastructure*. McKinsey & Company.

Easymile. (2022). *Large autonomous, on-demand public transport service launches in Germany*. https://easymile.com/news/large-autonomous-demand-public-transport-service-launches-germany (accessed 20.12.2022).

Hasan H. M., & Van Hentenryck, P. (2021). The benefits of autonomous vehicles for community-based trip sharing. *Transportation Research Part C. Emerging Technologies*, *124*. https://doi.org/10.1016/j.trc.2020.102929

Hevelke, A., & Nida-Rümelin, J. (2015). Responsibility for crashes of autonomous vehicles: An ethical analysis. *Science and Engineering Ethics*, *21*(3), 619–630. https://doi.org/10.1007/s11948-014-9565-5

https://www.wroclaw.pl (accessed 8.01.2023).

Huber, D., Viere, T., Horschutz Nemoto, E., Jaroudi, I., Korbee, D., & Fournier, G. (2022). Climate and environmental impacts of automated minibuses in future public transportation. *Transportation Research Part D. Transport and Environment*, *102*. https://doi.org/10.1016/j.trd.2021.103160

Lécureux, B., & Kaddoura, I. (2021). Sensitivity of the urban transport system to the value of travel time savings for shared autonomous vehicles. A simulation study. *Procedia Computer Science*, *184*, 686–691. https://doi.org/10.1016/j.procs.2021.03.086

Li, J., Zhao, X., Cho, M. J., Ju, W., & Malle, B. F. (2016). *From trolley to autonomous vehicle: Perceptions of responsibility and moral norms in traffic accidents with self-driving cars.* SAE Technical Paper No. 10. https://doi.org/10.4271/2016-01-0164

Liu, H. Y. (2017). Irresponsibilities, inequalities and injustice for autonomous vehicles. *Ethics and Information Technology*, *19*(3), 193–207. https://doi.org/10.1007/s10676-017-9436-2

Manivasakan, H., Kalra, R., O'Hern, S., Fang, Y., Xi, Y., & Zheng, N. (2021). Infrastructure requirement for autonomous vehicle integration for future urban and suburban roads – Current practice and a case study of Melbourne, Australia. *Transportation Research Part A. Policy and Practice*, *152*, 36–53. https://doi.org/10.1016/j.tra.2021.07.012

McManus, R. M., & Rutchick, A. M. (2019). Autonomous vehicles and the attribution of moral responsibility. *Social Psychological and Personality Science*, *10*(3), 345–352.

Menon, N., Barbour, N., Zhang, Y., Pinjari, A. R., & Mannering, F. (2019). Shared autonomous vehicles and their potential impacts on household vehicle ownership: An exploratory empirical assessment. *International Journal of Sustainable Transportation*, *13*(2), 111–122. https://doi.org/10.1080/15568318.2018.1443178

Neumann, T. (2018). Prospects for the use of autonomous vehicles in road transport in Poland *Autobusy: Technika, Eksploatacja, Systemy Transportowe*, (12). https://doi.org/10.24136/atest.2018.499

NHTSA. (n.d.). *Automated vehicles for safety*. https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety (accessed 13.01.2023).

Pettigrew, S., Talati, Z., & Norman, R. (2018). The health benefits of autonomous vehicles: Public awareness and receptivity in Australia. *Australian and New Zealand Journal of Public Health*, *42*, 480–483. https://doi.org/10.1111/1753-6405.12805

Plan zrównoważonej mobilności dla miejskiego obszaru funkcjonalnego Wrocławia. https://bip.um.wroc.pl/artykul/305/59093/plan-zrownowazonej-mobilnosci-dla-miejskiego-obszaru-funkcjonalnego-wroclawia (accessed 5.01.2023).

Robaczyński, W. (2022). Odpowiedzialność za szkody wyrządzone przez pojazdy autonomiczne. *Forum Prawnicze*, *1*(69), 67–84.

Runge, J. (2006). *Metody badań w geografii społeczno-ekonomicznej*. Wydawnictwo Uniwersytetu Śląskiego.

SAE. (2021a). *SAE Levels of Driving Automation™ Refined for Clarity and International Audience*. https://www.sae.org/blog/sae-j3016-update (accessed 13.01.2023).

SAE. (2021b). *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles, J3016_202104*. https://www.sae.org/standards/content/j3016_202104/ (accessed 13.01.2023).

Shafiei, S., Gu, Z., Grzybowska, H., & Cai, C. (2021). Impact of self-parking autonomous vehicles on urban traffic congestion. *Transportation*, *50*, 183–203. https://doi.org/10.1007/s11116-021-10241-0

SHOW. (n.d. a) *About SHOW*. https://show-project.eu/objectives/ (accessed 22.01.2023).

SHOW. (n.d. b) *Pilot sites*. https://show-project.eu/sites/ (accessed 22.01.2023).

SHOW. (n.d. c) *The Consortium*. https://show-project.eu/the-consortium/ (accessed 22.01.2023).

Silva, Ó., Cordera, R., González-González, E., & Nogués, S. (2022). Environmental impacts of autonomous vehicles: A review of the scientific literature. *Science of The Total Environment*, *830*, 154615. https://doi.org/10.1016/j.scitotenv.2022.154615

Sohjoa Last Mile. (2012). *Accelerating evolution of mobility in the Baltic Sea Region – Sohjoa Last Mile's robot bus pilot experiences*. https://www.sohjoalastmile.eu/2021/12/29/accelerating-evolution-of-mobility-in-the-baltic-sea-region-sohjoa-last-miles-robot-bus-pilot-experiences/ (accessed 14.01.2023).

Steck, F., Kolarova, V., Bahamonde-Birke, F., Trommer, S., & Lenz, B. (2018). How autonomous driving may affect the value of travel time savings for commuting. *Transportation Research Record: Journal of the Transportation Research Board*, *2672*(46), 11–20. https://doi.org/10.1177/0361198118757980

Stern, R. E., Chen Y., Churchill, M., Wu, F., Delle Monache, M. L., Piccoli, B,, Seibold, B., Sprinkle, J., & Work, D. B. (2019). Quantifying air quality benefits resulting from few autonomous vehicles stabilizing traffic. *Transportation Research Part D. Transport and Environment*, *67*, 351–365. https://doi.org/10.1016/j.trd.2018.12.008

Strategia rozwoju miasta Płocka do 2030 roku (2018). https://nowy.plock.eu/strategia-rozwoju/ (accessed 8.01.2023)

Strategia rozwoju miasta Rzeszowa do roku 2025. (2015). https://bip.erzeszow.pl/74-wladze-miasta-akty-prawa-budzet/60963-strategia-rozwoju-miasta-rzeszowa.html (accessed 8.01.2023).

Strategia rozwoju miasta Włocławek 2030+. (2021). https://www.wloclawek.eu/strona-4170-dokumenty.html (accessed 8.01.2023).

Strategia zrównoważonego rozwoju transportu do 2030 roku. (2018). https://www.gov.pl/web/infrastruktura/projekt-strategii-zrownowazonego-rozwoju-transportu-do-2030-roku2 (accessed 8.01.2023).

Ushakov, D., Dudukalov, E., Kozlova, E., & Shatila, K. (2022). The Internet of Things impact on smart public transportation. *Transportation Research Procedia*, *63*, 2392–2400. https://doi.org/10.1016/j.trpro.2022.06.275

Yuen, K. F., Choo, L. Q., Li, X., Wong, Y. D., Ma, F., & Wang, X. (2022). *A theoretical investigation of user acceptance of autonomous public transport. Transportation*. Springer. https://doi.org/10.1007/s11116-021-10253-w

Zhang, T., Tao, D., Qu, X., Zhang, X., Lin, R., & Zhang, W. (2019). The roles of initial trust and perceived risk in public's acceptance of automated vehicles. *Transportation Research Part C. Emerging Technologies*, 98, 207–220. https://doi.org/10.1016/j.trc.2018.11.018

Zhang, W., & Guhathakurta, S. (2017). Parking spaces in the age of shared autonomous vehicles: How much parking will we need and where? *Transportation Research Record*, *2651*(1), 80–91. https://doi.org/10.3141/2651-09

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