CARPOOLING IN TRANSPORT IN TODAY'S ICT - BASED ECONOMY

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Resume

The purpose of this research was, among other things, to show that the carpooling model can be regarded as a manifestation of collective intelligence and a response to the crisis of sustainability in today's ICT-based economy, which makes carpooling services a cheaper alternative to transportation services provided by other modes of transport: train and bus. The main research problem is contained in the question: How do collective intelligence and the tenets of sustainability influence the popularity of carpooling and the lower cost of carpooling services, compared to those provided by other forms of transportation? The critical literature analysis method, the comparison method and the statistical method, among others: the Mann Whitney U test and the Kruskal Wallis ANOVA test, were used in implementation of the study.

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1 Introduction

In the context of the development of renewable energy in Poland, the integration of technology and infrastructure plays a crucial role in forming a sustainable energy system. Poland is actively developing various sectors of renewable energy, including wind, solar, bioenergy, hydropower, and geothermal energy. This is driven by both national ambitions to reduce the carbon emissions and commitments to the European Union. At the same time, the electrical engineering sector provides critical support for this transition by developing infrastructure for the generation, storage, and distribution of renewable energy. Special attention is given to the creation of smart grids, which allow the efficient integration of various sources of renewable energy into the national grid.

One important aspect of this transformation is the development of electric vehicles (EV) and the supporting infrastructure, which has significant potential to reduce reliance on fossil fuels in the transportation sector. In this context, carpooling, or the shared use of cars, acquires new dimensions through the use of electric vehicles, which reduce the environmental footprint of travel. The electrical engineering sector facilitates this process by developing the charging stations, fast-charging technologies, and energy management systems that ensure efficient resource use.

Today, transportation is becoming easier and more accessible to everyone, among other things, through the implementation of innovations into economic and social life, as well as the ongoing evolution of technology, which can be seen in almost every area of human activity [1].

With the development and acceptance of the sharing economy, the popularity of mobile Internet technology, and the application of innovative technologies in many cities, online services and platforms have emerged to facilitate carpooling services. Online carpooling platforms can effectively match unfamiliar drivers and passengers in terms of both time and routes, enabling the large-scale carpooling to develop [2]. Carpooling is thus an informal form of shared rides for example among commuters [3-4].

Carpooling with EVs is also supported by the development of platforms for finding fellow travellers and optimizing routes, which reduces overall energy consumption and enhances the efficiency of transportation systems. Poland, aiming to become a leader in renewable energy, actively attracts European funds and investments to implement projects that contribute to reducing the greenhouse gas emissions and enhancing energy security. Meanwhile, the government is implementing various policy measures, including subsidies and tax incentives, to stimulate investment in renewable energy and electric transport. The development of these areas creates a synergistic effect, where innovations in one sector support and strengthen others, ensuring the sustainable and environmentally responsible development of the country.

The purpose of this research was to define what the carpooling is and demonstrate that the carpooling model can be seen as a manifestation of collective intelligence and a response to the sustainability crisis in today's ICT-based economy. This makes carpooling services a cheaper alternative to transportation services provided by other means of transport: train and bus.

The main research problem was defined in the form of the following question: "How do collective intelligence and the assumptions of sustainable development influence the popularity of carpooling and the lower cost of carpooling transportation compared to transportation provided by other means of transport?"

The authors posed three problem questions, which supplement the main problem formulated above.

1. How does smart grid integration affect the functioning of carpooling?
2. What is the carpooling phenomenon and what are its possibilities for the development of transport services?
3. How does carpooling influence the development of the concept of sustainable development?

To achieve the main objective of the research and solve the problem posed, the authors used an analysis of the cost of travel by three means (forms) of transportation: via the BlaBlaCar service, by Intercity train and by available bus service from one voivodeship city, i.e. Wroclaw, to the other 17 voivodeship cities in Poland in the period before the Covid-19 pandemic (2017-2018) and after the pandemic (2023 - March 2024).

In the implementation of the study, the method of critical analysis of the literature, the comparative method and the statistical method were used, including Mann Whitney U test and Kruskal Wallis ANOVA test. The choice of research methodology was not random; it was an arrangement of specific stages of the research procedure. One should agree with Czakon [5], an authority on research methodology in Poland, that classical research methods include observation, critical analysis of the literature, text analysis, and statistical research. The method used was triangulation, which, according to Ziolo [6]; "refers to the situation when a study uses several research methods in one study or different research techniques within one method. By using different research methods, triangulation increases the cognitive possibilities in relation to the studied phenomena". Authors made a deliberate choice of such research methods primarily because of the limited information and databases. The deliberate selection of research methods made it possible to supplement, deepen and confirm the existing state of knowledge.

2 Electricity industry in Poland

Poland is actively developing its electrical engineering sector, focusing on the implementation of innovative technologies and the creation of smart grids. Smart grids enable real-time monitoring and management of energy flows, which is crucial for stable energy supply in the face of growing demand and the instability of traditional energy sources. These grids make it possible to optimize the use of electricity, minimize losses, and improve the quality of energy supply.

The innovative technologies being implemented in Poland's electrical engineering sector include the development of new energy storage solutions, such as advanced battery systems, as well as the development of infrastructure for electric vehicles. In recent years, significant attention has also been given to demand management technologies, which allow for more efficient regulation of electricity consumption according to its availability and cost. Smart grids enable balancing energy production and consumption in real-time, contributing to the stability and reliability of energy supply. Additionally, they enhance the security of the power grid and provide the capability for rapid response to emergency situations.

The integration of smart grids and carpooling represents a synergistic advancement towards a more sustainable and efficient energy and transportation system. Smart grids, which are advanced electrical grids enhanced with communication, automation, and IT systems, enable the real-time monitoring and management of energy production, distribution, and consumption. Those grids are pivotal in integrating renewable energy sources, such as solar and wind, into the energy network, ensuring a stable and reliable supply despite the intermittent nature of these sources. By optimizing energy flows and enabling demand-response mechanisms, smart grids facilitate the efficient use of renewable energy, reduce peak loads, and enhance the overall resilience of the energy system.

Carpooling, on the other hand, is an effective strategy to reduce traffic congestion, lower carbon emissions, and decrease individual transportation costs. When integrated with electric vehicles (EVs) and supported by smart grid infrastructure, carpooling can achieve even greater environmental and economic benefits. Smart grids play a crucial role in this integration by providing the necessary infrastructure for widespread EV charging. They ensure that the increased demand for electricity from EVs can be met sustainably by optimizing the charging times and locations based on grid conditions and renewable energy availability.

Moreover, the smart grids can support the implementation of advanced carpooling platforms that use data analytics and real-time information to optimize routes and match passengers efficiently. These platforms can leverage smart grid data to recommend the best times and locations for charging EVs used in carpooling, thereby minimizing wait times and maximizing the use of renewable energy. Additionally, vehicle-to-grid (V2G) technology, enabled by smart grids, allows EVs to feed stored energy back into the grid during the peak demand periods, further stabilizing the energy supply and providing an additional revenue stream for carpooling participants.

The interplay between smart grids and carpooling also encourages the adoption of sustainable mobility solutions. As smart grids facilitate the reliable and efficient use of renewable energy, they make the operation of EVs more economical and environmentally friendly. This, in turn, promotes the use of EVs in carpooling, amplifying the reduction in greenhouse gas emissions and reliance on fossil fuels. Furthermore, policy measures and incentives, such as subsidies for EV purchases and investments in smart grid technology, can accelerate the adoption of both smart grids and carpooling, fostering a holistic approach to sustainable urban mobility and energy management.

Improvement of battery technology for EVs is another key area where the electrical engineering sector enhances efficiency and range, critical for ensuring the effectiveness of carpooling. Additionally, intelligent transportation systems, evolving within the electrical engineering sector, incorporate communication, navigation, and autonomous vehicle technologies, which also contribute to optimizing carpooling processes. These systems enable effective vehicle management and energy savings.

3 Carpooling - characteristics of the model of today's ICT-based economy

A critical analysis of the literature allows to conclude that carpooling, as a mode of the so-called social travel, has not yet received sufficient attention. Undoubtedly, the lack of analysis and research results of this phenomenon, despite its many different advantages, is an important factor limiting the consideration of this model from the perspective of scientific theory and practice. This is an important limitation, if only because carpooling in many cities is promoted as the so-called green transportation, allowing to reduce transport congestion, improve the natural environment [7-8], shaping a sustainable and healthy transportation policy, but also a model that has an impact on health, which is affected by air emissions and greenhouse gases as a consequence of excessive transport traffic [9]. Carpooling is also one of the most representative initiatives to promote the responsible use of private vehicles [10].

In a broad sense, carpooling refers to shared car trips between people with similar destinations [11-12]. According to Minet et al., a carpooling system typically involves riding in a car taking into account the sharing of travel/travel costs. A carpooling service requires finding people with similar travel schedules and routes, but it can also include matching preferences in terms of listening to radio stations, smoking, or gender [13].

Carpooling is one of the many alternatives to commuting, etc., promoted by transportation policies to reduce the number of vehicles on the road. It became popular during World War II, mainly because of the need to cope with oil and tires shortages, as well as the need to conserve resources for the war. Carpooling was also popular in the 1970s, when the motive for its spread was to reduce oil consumption during the oil crisis [14]. It thus became an important trend in the transportation services market. Carpooling was also a response to driving restrictions and was also promoted during the 2008 Beijing Olympics.

Carpooling gained popularity after the emergence of the Internet and mobile technologies. These applications, after becoming more widespread and popular in the 1930s and 1970s, have gained in importance again, and in the last decade or so the carpooling has grown in scale and number of users [15-16].

Nowadays, carpooling is a part of mobility management policies due to the issue of sustainable transportation, among other things, including the many opportunities it brings. These include:

- reduction in kilometers travelled,
- reduction in fuel consumption,
- reduction of pollution, including, besides the other things, the negative impact of air pollution [17-18],
- contribution to reducing the carbon footprint,
- reduction of traffic congestion and problems related to finding a parking space [19],
- reduction in traffic congestion and noise nuisance,
- reduction of social inequalities that arise when the poor perceive that transportation services are increasingly unavailable to this social group [20-23]. As the study of the correlation between the socio-demographic characteristics and usage elements show, lower-income users are more likely to be passengers, while the higher-income users carpool mainly as drivers [24].

All of these policies of sustainable mobility and demand management for transport and its services are implemented to use the transport system to meet lifestyle needs [25-26].

Indeed, carpooling is a so-called "potential new path to sustainability" and "sustainable lifestyles" [27].

Other benefits of the carpooling model include reducing the number of cars on the road while reducing traffic jams, emissions and noise, as well as saving time, parking space and accidents. Carpooling is also an opportunity to socialize and reduce the stress of commuting [28]. According to the study, carpooling also affects the social sphere, including the development of human capital, allowing people to make social connections and engage in various social activities [29].

The aforementioned attributes and advantages of carpooling are also accompanied by certain disadvantages, limitations and obstacles. These include the necessity to ensure passenger safety, suboptimal mobility matching and the requirement for time flexibility. In addition, a common aspect of the aforementioned obstacles may also be an implicit psychological barrier that makes carpooling less attractive [30].

In addition, the vague and flexible nature of carpooling (e.g., no fixed stops, the possibility of making detours) may hinder the acceptance of carpooling in society [31]. In addition to the traditional concept of carpooling, the literature also encounters the term "casual carpooling" (also known as "slugging"), which reflects a type of informal carpooling of an ad hoc nature. According to the terminology, these are impromptu carpools with three or more people commuting in a configuration of one driver and two or more passengers. Such shared rides usually take place in or near public transportation centers generally in the morning (less often in the evening), when those interested in this particular mode of transportation enjoy commuting to a common place of employment [32].

4 The development of carpooling vs. collective intelligence and the sustainability

Collective intelligence is the kind of collective action that uses the knowledge and work of its users to provide data to an application and improve its usability. Popular examples of collective intelligence are applications labelled Web 2.0., based on which online platforms facilitate collaboration and information sharing among users. Taking collective intelligence as a fundamentally different way of looking at how applications are used, they can support interactions of a social and economic nature, as well as facilitate decision-making. While until recently most traditional applications have focused on improving productivity, today's approach to collective intelligence is based on using the intelligence of groups of people to enable greater productivity and better decision-making [33].

The main principles of collective intelligence are based on two main aspects: collective problem solving and the wisdom of the crowd. Collective problem-solving generally concerns the optimal design of communication networks in organizations and determines the results of problem-solving through information efficiency. The wisdom of the crowd, on the other hand, indicates that the average response of a large group of novices may be more accurate than the opinions of individual experts [34].

The spread of simple and easy-to-use technologies that allow users to interact and design web applications without programming skills has led to previously unknown amounts of user-generated content [35].

Digital platforms offer the potential to bring people and knowledge together like never before. Initiatives that use digital platforms to focus and activate large groups of people and their knowledge to address challenges in all areas of social and economic life are emerging in increasing numbers [36]. One example of the solution described is shared smart mobility, which is reflected in carpooling. It corresponds to a form of sustainable mobility. This happens when it combines three categories of benefits compared to traditional mobility and transportation:

- economic (e.g., sharing ownership and maintenance costs);
- environmental (e.g., reducing negative externalities, traffic congestion, greenhouse gas emissions and noise),
- social-ethical (better accessibility, higher well-being and quality of life, social inclusion) [37].

According to Gandia et al [38] "smart mobility is characterized by the desire to inject more flexibility into travel, to discover new modes of transportation and sharing experiences. It offers the opportunity to eliminate entry barriers into the mobility market, whether economic (a one-way ticket) or technological variables (for example, smartphone use). It is the desire to propose sustainable mobility in the sense of submitting eco-innovations that reduce environmental impacts (less pollution, and zero tickets) or social consequences (disabled access) and that promote equality of territories (inclusiveness)".

5 Carpooling, train and bus trips between selected cities in Poland in 2017-2018 and 2023- 2024 - survey results

Montenero [39] reports that online platforms are transforming transport because they create new multilateral markets that connect transport providers (often non-professionals) and passengers in ways that generate new network effects and distribute them among ecosystem participants. Experiences of carpooling show that transport platforms can multiply traditional resource sharing and even replace mass transport modes such as rail and buses.

BlaBlaCar, which is one of the most popular carpooling platforms in Europe, is a platform that enables communication, negotiation and especially cooperation between users. This form of user activity is regarded as a manifestation of collective intelligence, based on the principles of collective problem-solving and the wisdom of the crowd, but is also an example of a tool that can support sustainable development and respond to its crisis.

The carpooling model, developed and implemented by users through BlaBlaCar, has emerged primarily because its use in the economy is considered to be competitive in terms of price with traditional transport models: rail and bus. The study covered carpooling transportation by BlaBlaCar, rail and bus between Wroclaw and other voivodeship cities in Poland in 2017-2018 (i.e., before the Covid-19 pandemic) and in 2023-2014 (i.e., after the pandemic).

In Figure 1, box plots show average ticket prices on individual routes between Wroclaw and other voivodeship cities in Poland in two periods: 2017-2018 and 2023-2024. This visualization not only confirms the overall increase in prices but also highlights greater variability in fare levels, which may reflect differences in demand intensity, vehicle availability, or platform usage patterns between regions. Comparing the two periods, one can see a clear increase in ticket prices on individual routes between Wroclaw and other voivodeship cities of Poland, but one can also note an increase in the variation of ticket prices on individual routes, as indicated by the width of the box and whiskers. In the first period of 2017-2018, the highest ticket prices were recorded on the Wroclaw - Bialystok route (by an average of about PLN 91.30; EUR 21.46) and on the Wroclaw - Gdansk route (by PLN 83.20; EUR 19.56), while in the second period, i.e. 2023-2024, the highest fare prices were on the Wroclaw - Lublin route (by an average of about PLN 121.9; EUR 28.65) and on the Wroclaw - Bialystok route (PLN 108.80; EUR 25.57), as well as on the Wroclaw - Olsztyn route (the average price in the period under review was about PLN 108.00; EUR 25.39).

In addition, it was checked whether there were statistical differences in average travel costs during the periods studied. The Mann Whitney U test was used for the study, and the tests were conducted at the significance level of $\alpha = 0.05$ (see Table 1). The study found that in most trips between Wroclaw and other voivodeship cities in Poland, the differences were statistically significant $p < \alpha$. The exceptions were the routes from Wroclaw to Bialystok $p > \alpha$ ($p = 0.1110$), from Wroclaw to Bydgoszcz $p > \alpha$ (0.9245), from Wroclaw to Olsztyn $p > \alpha$ ($p = 0.0742$) and from Wroclaw to Torun $p > \alpha$ ($p = 0.3111$). The price increase (change) was not statistically significant. In other cases, the test showed significant differences in average travel costs (ticket prices).

Figure 2 shows the average ticket prices with regard to the means of transport grouped by the analyzed periods 2017-2018 and 2023-2024. It is evident that while the bus and carpooling prices have increased

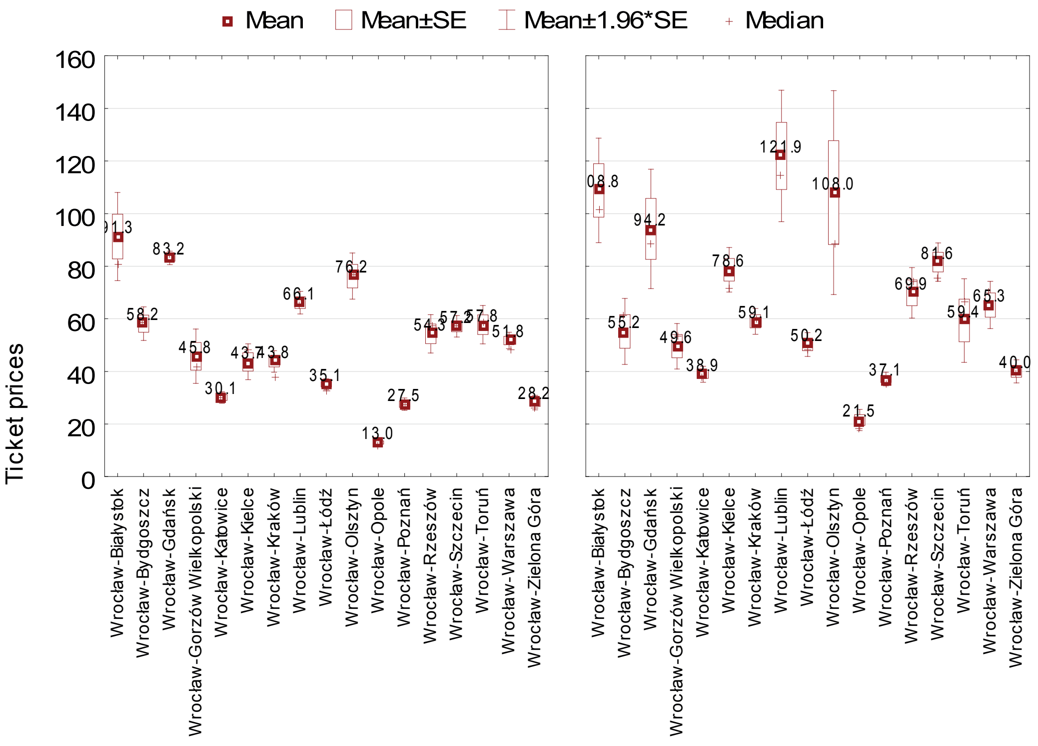

Figure 1 *Average travel costs on selected routes between Wroclaw and other voivodeship cities in Poland in 2017-2018 and 2023-2024, based on [40] and data from [41], [42] and [43]*

***Table 1** Results of Mann Whitney U test, based on [40] and data from [41], [42] and [43]*

	2017-2018						2023-2024						
	N	Me	Average	σ	Min	Max	N	Me	Average	σ	Min	Max	p-value
Wroclaw-Bialystok	7	81	91.3	22.6	69	122	9	102.0	108.8	30.4	47.0	140.0	0.1110
Wroclaw-Bydgoszcz	14	58	58.2	12.1	36	71.5	9	61.0	55.2	19.2	14.0	70.0	0.9245
Wroclaw-Gdansk	14	84.5	83.2	4.8	71	89	10	88.5	94.2	36.6	23.0	155.0	0.6385
Wroclaw-Gorzow Wielkopolski	27	42	45.8	27.4	25	177	15	53.0	49.6	17.1	15.0	70.0	0.0139*
Wroclaw-Katowice	39	30	30.1	7.0	15	43	24	37.2	38.9	7.7	20.0	54.0	0.0000***
Wroclaw-Kielce	19	48	43.7	15.2	6	64	17	72.0	78.6	17.8	60.0	130.0	0.0000***
Wroclaw-Krakow	35	38	43.8	12.3	30	78	24	59.5	59.1	12.3	35.0	86.0	0.0000***
Wroclaw-Lublin	17	65	66.1	9.1	48	85.5	15	115.0	121.9	49.5	53.6	245.0	0.0000***
Wroclaw-Lodz	31	33	35.1	5.9	28	53.45	20	48.1	50.2	10.3	39.0	80.0	0.0000***
Wroclaw-Olsztyn	13	77	76.2	16.1	48	122	5	88.0	108.0	44.2	68.0	175.0	0.0742
Wroclaw-Opole	31	12	13.0	3.5	11	29	15	18.0	21.5	7.9	9.0	39.5	0.0000***
Wroclaw-Poznan	31	27	27.5	6.7	14	46.95	25	35.0	37.1	6.7	27.0	53.0	0.0000***
Wroclaw-Rzeszow	16	57.5	54.3	14.9	16	83	8	74.1	69.9	13.9	39.9	82.0	0.0146***
Wroclaw-Szczecin	19	57	57.2	9.1	42	77	17	75.0	81.6	15.4	61.2	105.0	0.0000***
Wroclaw-Torun	9	59	57.8	11.2	36	73	8	67.0	59.4	22.9	17.0	84.0	0.3111
Wroclaw-Warszawa	31	48	51.8	8.9	36	75	23	71.0	65.3	22.0	15.0	92.0	0.0005***
Wroclaw-Zielona Gora	36	26.5	28.2	8.5	12	47.5	17	39.0	40.0	9.2	20.0	60.0	0.0000***
all groups	389	40	43.6	21.6	6	177	261	58.0	61.6	32.6	9.0	245.0	

considerably, the average costs of rail travel remained relatively stable or even slightly decreased, which may indicate different pricing strategies or levels of subsidy. In this case, it is also possible to observe an increase in prices for each means of transport grouped by the studied periods. From the data included in Figure 2, it is clear that the average prices in the analyzed periods increased for BlaBlaCar and bus trips, while they slightly decreased for train trips (i.e., Intercity).

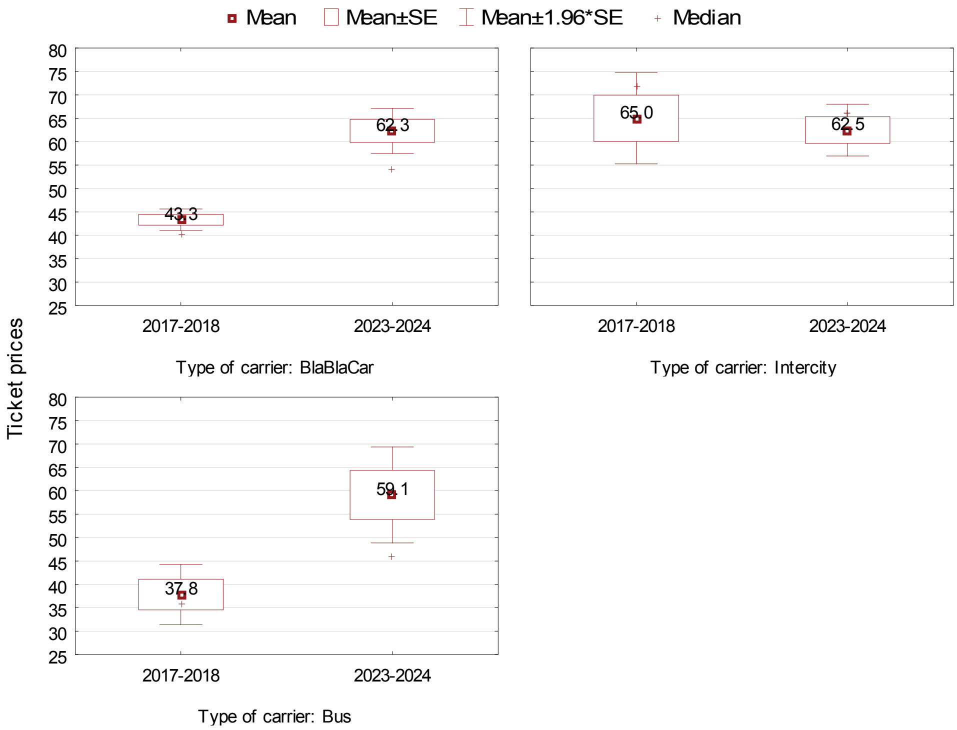

***Figure 2** Average cost of travel by selected means of transport: BlaBlaCar, rail, and bus between Wroclaw and other voivodeship cities by period under study, based on [40] and data from [41], [42] and [43]*

Table 2 *Results of the Mann Whitney U test, based on [40] and data from [41], [42] and [43]*

	2017-2018						2023-2024						
	N	Me	Average	σ	Min	Max	N	Me	Average	σ	Min	Max	p-value
BlaBlaCar	347	40	43.3	21.6	11	177	169	54	62.3	31.9	16	245	0.0000***
PKP Intercity	12	71.6	65.0	17.2	29	85.5	32	66.2	62.5	16.0	19.6	88	0.5067
bus journeys	30	19	37.8	18.1	6	78	60	45.9	59.1	40.6	8.9	174.9	0.0358*

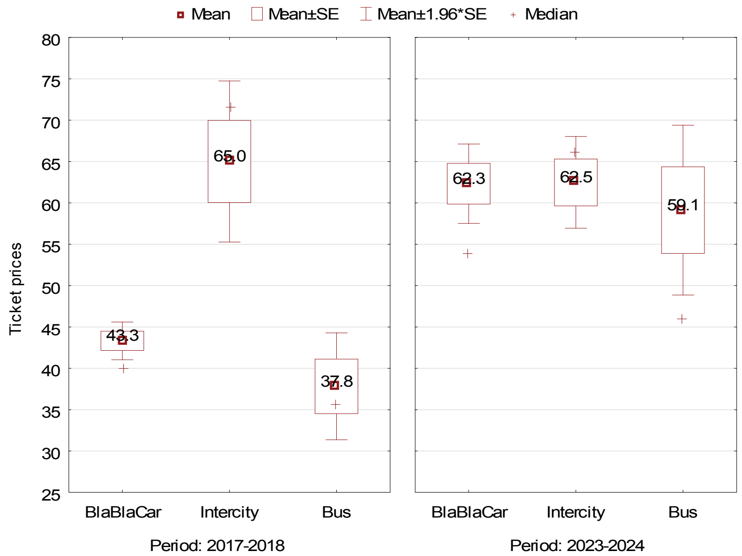

Figure 3 *Comparison of average ticket prices between Wroclaw and other voivodeship cities in Poland within each carrier group: BlaBlaCar, train trips and bus trips in 2017-2018 and 2023-2024, based on [40] and data from [41], [42] and [43]*

It was checked whether the differences in the average costs of a ride between Wroclaw and other voivodeship cities were statistically significant in the studied periods in each group of carriers. Mann-Whitney U-test was used for the study and a significance level of α =0.05 was adopted. The analysis showed that statistically significant differences in ticket prices occurred for BlablaCar rides p < α (p = 0.0000) and bus rides p < α (p = 0.0358). In contrast, differences in the cost of rail travel (i.e., Intercity) were not statistically significant.

Analyzing the data, it can be seen that the average prices of rides for BlaBlaCar increased during the periods studied: in 2017-2018 the average was PLN 43.3 (EUR 10.18) and the median PLN 40 (EUR 9.40), while in the period 2023-2024 the average price rose to PLN 62.3 (EUR 14.64) and the median PLN 54 (EUR 12,69). Bus rides also recorded an average increase in fare prices, and the differences were statistically significant, as well, p < α (p = 0.0358). In 2017-2018, the average was PLN 37.8 (EUR 8.88) and the median was PLN 19 (EUR 4,46), while in the 2023-2024 period, the average price rose to PLN 59.1 (EUR 13.89) and the median to PLN 45.9 (EUR 10.79) (see Table 2).

Figure 3 shows the average ticket prices by different means of transport for the two periods studied: 2017-2018 and 2023-2024. The narrowing of price differences between the carriers in the latter period suggests increasing competition and convergence of perceived value among transport modes, especially between the carpooling and buses. A wide variation was noted in 2017-2018. The lowest ticket prices were for bus transportation – PLN 37.8 (EUR 8.88) and for Blablacar transportation – PLN 43.3 (EUR 10.18), while the highest average prices were for Intercity rail transportation (average PLN 65; EUR 15.28). In 2023-2024, the average prices of BlaBlaCar rides, train rides and bus rides equalized.

Thus, it was tested whether the differences in average fare prices between Wroclaw and other voivodeship cities are statistically significant between different carriers: BlaBlaCar, rail transport (Intercity) and bus rides in the studied periods of 2017-2018 and 2023-2024. The Kruskal Wallis ANOVA test was used for the study. The test was conducted at the significance level of α = 0.05. The test shows that the differences in 2017-2018 between the three studied carriers were statistically significant p < α (p = 0.0011). In the period 2023-2024, prices showed no statistically significant differences between carriers p > α (p = 0.0536) (see Table 3).

It was also tested whether the type of carrier (BlaBlaCar, Intercity train rides and bus rides) and the study periods (2017-2018 and 2023-2024) had simultaneous effects on fare levels. ANOVA analysis for factorial arrangements was used for the analysis. The study shows that both the study period and the type of carrier together have an impact on the transportation

***Table 3** Results of Kruskal Wallis ANOVA test, based on [40] and data from [41], [42] and [43]*

		BlablaCar	PKP Intercity	bus journeys	p-value
2017-2018	N	347	12	30	0.0011
	Me	40	71.6	19	
	Average	43,3	65	37.8	
	σ	21,6	17.2	18.1	
	Min	11	29	6	
	Max	177	85.5	78	
2023-2024	N	169	32	60	0.0536
	Me	54	66.2	45.9	
	Average	62.3	62.5	59.1	
	σ	31.9	16	40.6	
	Min	16	19.6	8.9	
	Max	245	88	174.9	

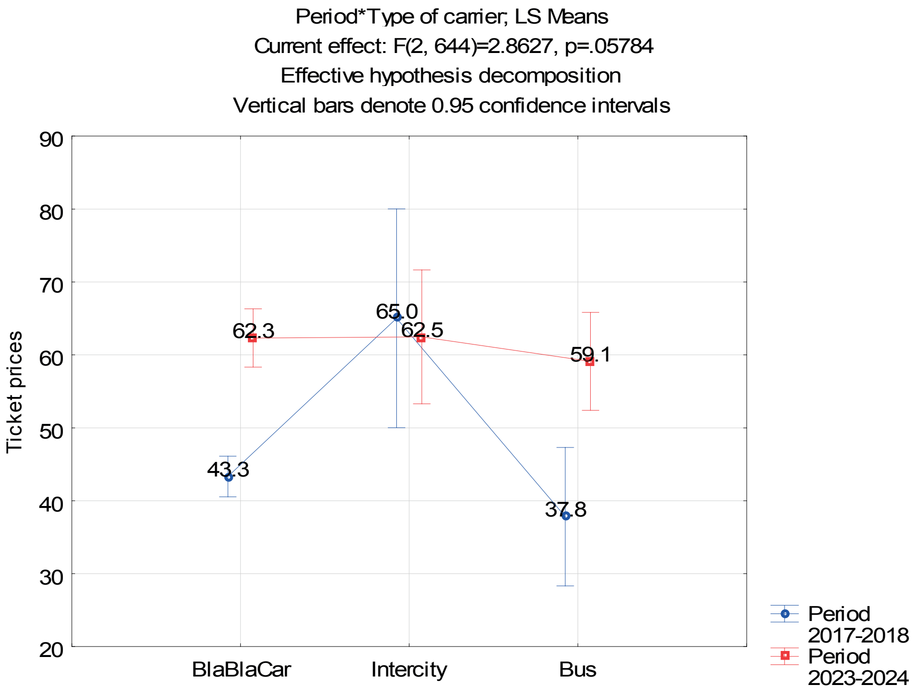

***Figure 4** Interaction graph between carrier type (BlaBlaCar, train rides and bus transfers) and period (2017-2018, 2023-2024) and ticket prices, based on [40] and data from [41], [42] and [43]*

costs, p < α (p = 0.0578). The results are shown in an interaction figure (see Figure 4).

The results of the survey indicate that in most of the surveyed trips between Wroclaw and other voivodeship cities in Poland in 2017-2018 and 2023-2024, trips provided by the carpooling model were cheaper than trips by rail and bus. The BlaBlaCar service, permanently supported by users and maintaining its growth momentum, can therefore be a manifestation of collective intelligence in today's high-tech economy. It is also an example of a service-application that fits into the concept of sustainable development and responds to the needs of modern society.

6 Summary

Carpooling is a model of shared travel that fits into the area of the so-called green transport, aiming, among other things, to protect the environment and reduce the so-called congestion in transport, i.e. traffic congestion. The model also corresponds to assumptions of the concept of sustainable development, which means that the implementation of trips through this model can contribute to the achievement of economic, social and environmental goals. This is expressed, among other things, in the generally lower cost of carpooling trips relative to the cost of trips made by train and bus, the reduction of negative environmental impacts, as well as the building of a community and a certain carpooling culture among users who form the described model. The stated goal of this research has been reached. The authors have shown that the carpooling model is regarded as a manifestation of shared intelligence and is a response to the crisis of sustainability in today's ICT-based economy. Carpooling services are a cheaper alternative to transportation services provided by other means of transport.

A critical analysis of the literature, as well as the results of the study, made it possible to solve the main research problem. Collective intelligence and the assumptions of sustainable development influence the popularity of carpooling and the lower costs of carpooling services compared to those provided by other means of transport due to, among other things, the typically social nature of the service, its co-creation and development, based on the assumptions of the wisdom of the crowd and collective problem-solving, and the promotion and implementation of goals of an ecological and environmental nature. From the point of view of economics and management, the carpooling model is generally regarded as a cheaper alternative in travel to other forms and means of transport.

The authors also solved specific problems. Regarding the first specific research problem, it was noted that the integration of smart grids affects the operation of carpooling, and the expression of this integration can be: new models based on smart solutions, as well as their application in mass transportation, also enabling shared transportation.

In response to the second research problem, it was recognized that the carpooling phenomenon is not only a model, a way or a tool, but a lifestyle for the younger generation and an opportunity to strengthen social ties, as well. Carpooling also offers opportunities for the development of transportation services due to the sharing of travel costs, the convenience of travel and the reduction of transportation congestion.

In response to the last specific problem, it was shown that carpooling can help to strengthen the sustainability effect in the local as well as national economy. This finding is supported by, among other things, lower travel costs, strengthening social relations and creating green patterns.

The results of the conducted study allow to formulate the following conclusions:

1. The carpooling model is one of the important models of the modern economy, with its roots in the 1930s and based on information and communication technologies.
2. Carpooling is an important model and form of traveling in the 21st century from the point of view of price competitiveness and non-economic attractiveness, allowing the achievement of various economic and environmental goals and objectives.
3. Carpooling is a source of competitive advantage and can be an important alternative to traditional modes of travel and/or movement.
4. Carpooling can be considered as a solution typical of collective intelligence, based on the principles of cooperation, partnership, creativity and the creation of new value.
5. The implementation of the carpooling model by drivers and passengers contributes to strengthening the assumptions of ecology, the so-called "green economy" and its community nature within the concept of sustainable development.

Potential barriers to the wider adoption of carpooling beyond the costs and sustainability include limited or no trust in fellow travellers, concerns about travel safety, the lack of universally accepted carpooling regulations, and changing trends in travel and increasing trends in carpooling. Electrical engineering - is a field of technology and science that deals with issues related to the generation, processing (transformation), transmission, distribution, storage and use of electricity. Areas of scientific interest in electrical engineering include electrical machinery and equipment, their construction, operation, management including in the field of electrical transportation. Engineering, including electrical engineering, has been the subject of scientific discussion for a long time. For example, F. A von Hayek and G. K. Mydral in 1974 [44] received the Nobel Prize for their analysis of the interdependence of economic and social factors. In electrical engineering they follow the thinking of these Nobel laureates "preferences or subjective evaluations of individuals" are decisive. These views were developed in Japanese descriptive economics." They state that the needs of electrical engineering are determined by the subjective needs of stakeholders and consumers. A similar trend is reflected in the views of another Nobel Prize winner in 1987 - R. M. Solow [44], who proclaimed that technology, (including electrical engineering) is the most significant factor in economic development. According to Solow [44], the real source of growth of economies is the innovative activity of the entrepreneur. Carpooling, as a system that makes the passenger car similar and compatible with mass transportation, through the use of electric cars, is based on electric engineering solutions and fits into the strategic structure of these solutions in the future. Carpooling, as a concept or model for the behavior of individuals, fits into today's problems of sustainable transportation, where the electric engineering solutions would be a challenge. This is a contemporary new area of scientific research. In transportation, electrical engineering has applications in: electric vehicle installations, including electric multiple units, catenary, linear motor-driven railroads, magnetic railroads, electrical equipment of ships (including submarines and torpedoes) and other vessels (including electric aircraft). It should be stressed that the main connection between carpooling and the electrical engineering industry is at three levels.

The authors recognized that carpooling is a complex and multifaceted topic, closely tied to various areas of socio-economic life. Despite its economic and environmental benefits, the widespread adoption of carpooling continues to face significant challenges, including behavioral barriers, such as lack of trust in strangers, concerns about punctuality and personal safety, and the desire for personal space. Those issues must be addressed for carpooling to achieve broader public acceptance. Looking ahead, future research and development should consider both the technological and human aspects of carpooling. On the technological side, advances, such as artificial intelligence, real-time data analytics, IoT-enabled infrastructure, and smart solutions (e.g., smart cities), offer promising opportunities to improve the efficiency, safety, and user-friendliness of carpooling platforms. The experience of digital transformation in other transport domains - such as smart parking systems at airports - demonstrates the potential of such tools to enhance accessibility and streamline operations. Applying similar principles to carpooling could lead to more robust, flexible, and attractive services. At the same time, further research should focus on the psychological and behavioral dimensions that influence user adoption. This includes exploring issues of trust, privacy, flexibility, and perceived safety through the mixed-method approaches, such as combining survey data with in-depth interviews or behavioral experiments, to gain a deeper understanding of user preferences and motivations.

From a broader perspective, the development of carpooling must also account for the dynamic economic and social landscape. In light of customers' growing tendency to reduce expenses - including those related to travel - and the increasing emphasis on environmental sustainability, carpooling models must evolve to reflect changing user expectations and societal needs. This includes adapting to new labor market models, the pervasive implementation of ICT tools, and emerging cyber threats [45].

To support this evolution, the authors recommend the following:

- Introduce clear and appropriate legal frameworks at national and international levels to regulate the rights and obligations of participants, cost-sharing methods, and consequences of legal violations.
- Develop carpooling models that facilitate efficient and transparent communication between travellers and expand accessibility to a broader audience.
- Design business models that align with the principles of sustainable development, integrating economic, social, and ecological dimensions.

By addressing both technological opportunities and behavioral challenges, and by supporting development through robust legal and institutional frameworks, carpooling can continue to evolve into a viable, sustainable, and widely accepted mode of transportation.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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