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The Future of Autonomous Vehicles in the Opinion of Automotive Market Users

Monika Stoma [1], Agnieszka Dudziak [1,*], Jacek Caban [2] and Paweł Droździel [2]

[1] Faculty of Production Engineering, University of Life Sciences in Lublin, Gleboka Street 28, 20-612 Lublin, Poland; monika.stoma@up.lublin.pl
[2] Faculty of Mechanical Engineering, Lublin University of Technology, Nadbystrzycka Street 36, 20-618 Lublin, Poland; j.caban@pollub.pl (J.C.); p.drozdziel@pollub.pl (P.D.)
* Correspondence: agnieszka.dudziak@up.lublin.pl

Abstract: Contemporary trends are focused on the development of the so-called smart, connected and multimedia cars as well as actions in the field of driving autonomy, and these trends may lead to changes in the structure of the industry through the emergence and growth of the importance of new entities. The article presents the concept of autonomous vehicles (AVs) and the way it is perceived by users of traditional cars. Surveys were carried out in various age groups on the possibilities of developing AVs in Poland. The group of respondents were inhabitants of a rural area, small towns and cities with over 300,000 inhabitants. Based on our own research, it can be concluded that, due to many different factors, including costs, legal regulations and conviction, among others, AVs will not appear so soon in common use on Polish roads. The results of the research showed that the majority of respondents consider hybrid vehicles (HVs) and then electric vehicles (EVs) to be the dominant type of vehicles in the near future in Poland, at the same time pointing at the long process of adopting AV technology.

Keywords: autonomous level; autonomous technology; vehicles; road traffic; survey study

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1. Introduction

The role of the automotive industry in industrialization is huge. This industry is one of the most important for the Polish economy. It is also responsible for a significant number of jobs, as well as many different investments and revenues for the public finance sector. Importantly, this industry directly or indirectly affects other sectors of the economy. Three technological megatrends of the fourth industrial revolution (Industry 4.0) are indicated, i.e., 1. Communication, 2. artificial intelligence and 3. flexible automation. The technology of the fully autonomous vehicle (AV) is best adapted to these megatrends, especially in the case of connected and autonomous vehicles (CAVs), which enable communication between vehicles, infrastructure and other road users (so-called V2X connectivity) [1,2]. Automated driving is a major trend in the automotive industry as it promises to increase road safety and driver comfort [3].

One of the key elements in the development of AV technology is the progress related to the conversion of vehicle drive systems to electric drives. Currently, more and more vehicle manufacturers offer hybrid or electric vehicles. This will certainly affect the development of the industry related to electric driving and increase the level of employment in these sectors of the economy. Over the past decade, significant progress has been made in the field of automated driving systems (ADS), and AV technology is gaining more and more attention from vehicle manufacturers, technology companies, decision makers and the general public. Recent dynamic changes in vehicle technology like advanced driver assistance systems (ADAS) (such as, e.g., automatic braking, automatic cruise control, intelligent speed assistance, line maintenance assistance systems, etc.) bring us closer to increasingly autonomous and independent vehicles, which will use these solutions.

This development is supplemented by the parallel development of connectedness and communication in vehicles. Therefore, taking into account current dynamics and progress, it can be expected that these systems will continue to develop, and the technology of automated driving will lead to a change in the paradigm in transport systems in terms of comfort of use, choice of mode and business models [4].

Autonomous vehicles include various vehicles, including passenger cars, trucks and drones, which are based on artificial intelligence with varying degrees of human participation. By processing and analyzing billions of data from a number of sensors, cameras and radar systems every second, AVs can effectively "see" the road and respond to changing conditions or overcome obstacles.

The ability of autonomous vehicles to operate without human intervention depends on their level of technological sophistication, in accordance with the current six-degree autonomy scale proposed by the International Society of Automotive Engineers (SAE) [5,6] (see Figure 1) from level 0 (without automation) to level 5 (full unlimited automation); levels 1 to 3 are considered "semi-autonomous":

- Level 0: the driver performs all tasks related to driving and there is no automation.
- Level 1 (Driver's assistant): It is implemented by systems that automate a specific element of driving, and the driver is obliged to keep their hands on the steering wheel and watch the traffic on the road. So, the driver controls most driving functions, but under certain conditions the vehicle may be able to adjust the cruise control speed or stay on the road lane.
- Level 2 (partial automation): Corresponds to semi-autonomous driving—in the case of traffic jams on the road, the vehicle can autonomously take over driving, steering and braking. The car can both accelerate/decelerate and perform basic steering functions. The driver is still responsible for steering the navigation (e.g., exit from the highway, change of lane or turn onto a new street).
- Level 3 (conditional automation): on-board systems are already able to take over all driving functions, but only in certain cases; however, the driver must be alert at all times and ready to take over—their car can therefore monitor the driving environment and accelerate, turn or brake, but still awaits human intervention upon notification.
- Level 4 (high automation): fully autonomous driving, vehicles communicate with each other and inform each other about, e.g., change of lane, and the driver does not have to constantly observe the surrounding traffic on the road; the car can control all aspects of driving and operate without human intervention, but only under certain conditions.
- Level 5 (full automation): the car is fully autonomous in all driving conditions and does not require human intervention—the technology system can perform all driving tasks in all circumstances, and the passengers are only passive passengers and never have to participate in driving and perform any driving tasks.

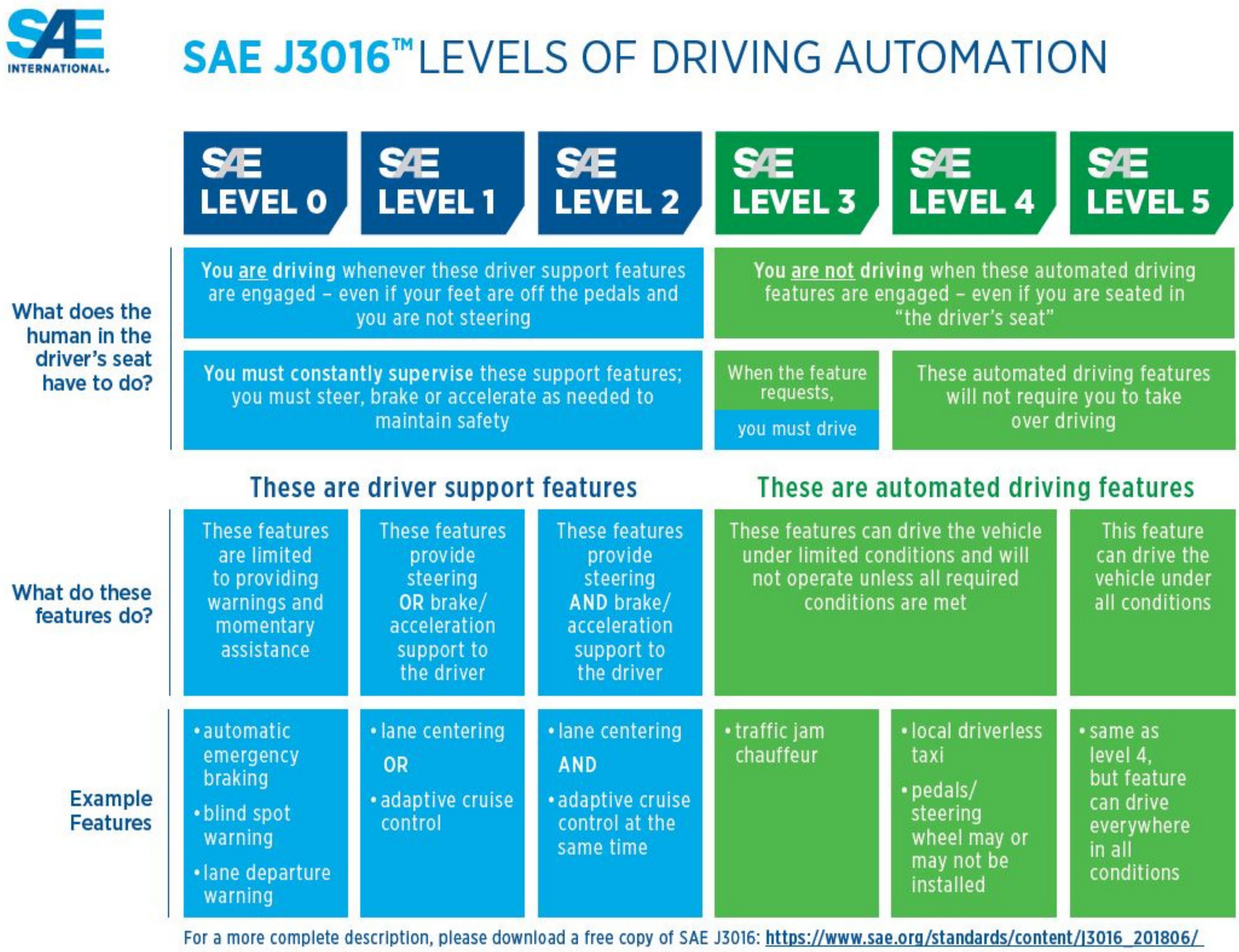


Figure 1. Level of driving automation proposed by SAE [7].

The latest car communication is designed to allow continuous, reliable and fast interaction between moving vehicles. They are usually divided into four use cases: vehicles to other vehicles (V2V), vehicles to the road-side infrastructure (V2I), vehicles to pedestrians (V2P), vehicles to devices (V2D) and vehicles to the cellular network (V2N). Together, these use cases are known as V2X—vehicles to everything [8]. It is anticipated that the wide-scale application of V2X technology can greatly improve transport safety and particularly significantly reduce vehicle collisions, especially in light vehicle accidents, by improving situational awareness. There are two types of V2X communication technology depending on the underlying technology being used: WLAN-based and cellular-based (C-V2X) technologies based on LTE [9–13]. Technology based on Wi-Fi is based on the standard IEEE802.11p for vehicular communication. It is also known as ITS-G5—Wireless short range to Intelligent Transport System, or DSRC—Dedicated Short-Range Communications (American or European protocol, respectively) [12]. C-V2X uses 3GPP—The Third Generation Partnership Project, 4G—The fourth generation, LTE—long-term evolution, or 5G—the fifth generation new radio (NR) connectivity to transmit and receive signals [13]. It uses two complementary transmission modes. The first is V2V, V2I and V2P. In this mode, C-V2X works independently of the cellular networks and it uses a PC5 interface for communication. The second mode is cellular network communications, in which C-V2X employs the mobile telephony network to enable vehicles to receive information about road and traffic conditions in the area. It uses LTE–Uu interface for communication, particularly for V2N [12,13].

AVs, despite the fact that they are still at an early stage of development and implementation, could mean a huge revolution not only in transport and the automotive industry, generating significant benefits in the long run in terms of transport accessibility, safety, traffic flow, emissions, fuel consumption and comfort. Many scientists believe that the large-scale deployment of AVs will bring about transformational changes in mobility and accessibility, travel patterns, safety and security, energy efficiency, emissions, employment, data availability, management and business models [14–16]. In the publications [17–20], the authors note the benefits for logistics and technical tasks in the workplace. Another aspect of the use of AVs is the management of urban space and the change in the demand for parking spaces depending on the change of ownership and shared use of autonomous vehicles (SAVs) [21,22]. SAVs represent an emerging alternative for driverless and no-demand transport [23], offering a compromise between private ownership and public transport [24]. Advanced technologies and systems used in this type of vehicles will also have a significant impact on other sectors of the modern market, such as trade, logistics, construction, insurance and related industries. A widespread transition to autonomous and electric vehicles would also change our daily lives. GM CEO Mary Barra refers to this future as “zero accidents, zero emissions and zero fatalities” [25]. In the literature on the subject, one can find many scientific papers on the vision zero perspective in various European countries [26–29]. These are, however, mainly papers about the “vision zero” concept as such, and there is only a limited number of empirical studies available. The European Union set out a “vision zero” target of reducing the number of fatal road accidents to almost zero by 2050. However, all these potential economic, ecological and social benefits will not be achieved until AVs are accepted and used by the majority of society [30,31]. Another important issue often raised in various studies is the regulation of legal issues [32–34], primarily concerning liability and security [35].

Another very important aspect related to AVs is the concept of smart cities, which practically focuses on the transformation of cities based on sustainable development. Smart city-related guidelines supply EU countries with general ideas on handling and controlling social, economic and technological change. Technologies for transport face the great challenges by globalization, re-urbanization and the change of social mobility behavior [36]. Passenger transportation is an indispensable and elementary service, in addition, there is a large share of freight traffic in urban areas. For their current problems there are several answers, one of them being smart cities’ sub-systems, or smart mobility [37,38]. Smart mobility can be divided into two segments: (1) innovative solutions and (2) development of current services. Innovative solutions are not present in every urban transportation system; however, they play a main role in smart mobility-oriented development [39]. AVs and EVs are tools on the vehicle side. Mobility as a service (MaaS) is a new concept [39], with which both demand-driven service planning and the personalization of services are possible.

One of the important and highly researched effects of AVs is their effect on urban space usage and parking tendencies. Parking services are also moving to automated solutions; P+R parking lots and connectivity with public transportation networks are the most important issues [36]. One of the latest research directions is urban space saving by normalizing parking issues. Even a third of the total traffic time during peak traffic periods is related to finding parking spaces in congested urban areas. The appropriate and adequate information about the number of free places, their location, etc., can reduce even by 30% the traffic volume in some cases [40]. The parking management has to be integrated in the traffic management and parking-related measures have to be adjusted to traffic management measures [40]. AVs also cope well with this problem thanks to V2V and V2I communication.

Due to the fact that AVs are currently undergoing various tests and have not yet been introduced to the market on a large scale, few people have been in contact with this technology so far. However, the concept itself raises a lot of controversy and doubt, and it seems that it still remains in the field of innovative solutions. As already mentioned, after analyzing the available literature, it was found that there are still few results of research carried out in this area, allowing for the assessment of the knowledge of the AV concept, its popularity, possibilities of implementation, as well as barriers inhibiting or even preventing its dissemination. This is particularly true for less urbanized, industrialized or typically agricultural areas, where smaller towns and rural areas predominate, and their inhabitants are often not up-to-date with modern technologies. Taking the above into account, the aim of the article is an attempt to partially fill the literature gaps, and hence to examine and assess the attitudes and perception of potential AV users and current users of traditional cars, of the concept of this type of vehicle, as well as to assess their development prospects, mainly through the prism of barriers and factors inhibiting the introduction of the analyzed solution on Polish roads.

2. Materials and Methods

In order to assess the prospects for the development of AVs in the assessment of their potential users, we conducted our own research in the group of adults over 18 years old, which resulted from the possibility of having a driving license. The study was carried out in two stages: a pilot study and a proper study. In the first stage a questionnaire, which was especially developed for the purpose of this study, was tested on a group of 10 randomly selected people. Based on the feedback from the pilot test, in the next stage of the research, the questionnaire was improved and the authors constructed the final version of the measurement tool used in the main research—a structured proprietary survey questionnaire.

The questions in the survey were mainly closed; they were developed unambiguously so that they did not require supplementary comments, and the respondents were asked to select one correct answer from several available options. Several of the questions were multiple choice questions, also with the option of giving your own answer, which was, however, always indicated in the questionnaire. The questionnaire, except for the metric questions, enabling the socio-demographic characteristics of the respondents due to various grouping variables, contained questions mainly about the following:

- Knowledge of autonomous vehicle technology;
- Attitude to this technology;
- Barriers and challenges resulting from the introduction of this technology.

The purpose of the survey was explained to the respondents, and the confidentiality of results was emphasized.

The way to collect information was to conduct a directed interview in four age groups, taking into account the sex of respondents, their place of residence and other grouping variables, mainly concerning driver status (as shown in Table 1). The random sampling method was used—simple random selection (without returning). Due to the fact that data were obtained by taking population samples, they can be considered as descriptive research based on the method of data collection, and more specifically—a survey. The number of the examined group was 579 people.

Table 1. Socio-demographic profile of the population surveyed.

Socio-Demographic Profile	Number of Respondents	Percentage Share [%]
Total	579	100.0
Gender:		
Female	219	37.8
Male	360	62.2
Age:		
19–25 years old	276	47.7
26–40 years old	140	24.2
41–60 years old	138	23.8
60 years and more	25	4.3

Table 1. *Cont.*

Socio-Demographic Profile	Number of Respondents	Percentage Share [%]
Place of residence:		
rural area	198	34.2
city to 100,000 residents	118	20.4
100,000–300,000 residents	58	10.0
city with more than 300,000 residents	203	35.4
Driving license:		
yes	506	87.4
no	73	12.6

The collected data were presented using graphs and then subjected to basic statistical analysis adequate to the nature of the variables.

3. Results and Discussion

To achieve the goal set in the study, the results obtained based on questionnaires were analyzed and presented in descriptive and graphic form. The majority of respondents were men, young people (18–25 years old), with secondary and higher education and living mainly in the countryside or in large cities (over 300,000 inhabitants). The detailed socio-demographic characteristics of the respondents are presented in Table 1.

Polish society is becoming more and more mobile, which can be seen, among other factors, by increasing car sales. The automotive industry is preparing for a revolution on many levels. The technical revolution concerns mainly the issue of driving—electrification is approaching fast. The industry's social responsibility requires investing in new, environmentally friendly driving options. This is a very serious challenge for manufacturers who have to prepare the entire network of suppliers for the new assortment, as well as the service network to handle it [41].

The concept of an AV is also part of the automotive market development strategy, but its perception by current drivers in Poland seems to be at a highly differentiated level.

3.1. Autonomy Levels in the Automotive Market

In recent years, various surveys of public opinion and user acceptance regarding the perception and adoption of ADS have been conducted worldwide [32,42,43]. Begg [44] developed a survey on the likelihood of AV adoption aimed at UK transport experts to establish their perceptions of whether and when interviewees expect AVs to become a reality. In this survey, 28% of respondents said vehicles with level 3 autonomous driving technology will be available on UK public roads by 2040, and almost 25% said that the implementation of AVs would improve road transport safety.

In turn, Kyriakidis et al. [45] conducted a public opinion poll on automated driving among 4886 respondents in 109 countries. In this survey, respondents indicated that fully automated driving (level 5) would be easier than manual driving, while partially automated driving (level 3) was perceived as more difficult. Concerns focused on the hacking and misuse of software, legal issues and security. In addition, 20% of respondents said they would be willing to pay USD 7000 more for a fully level 5 AV, and nearly 70% said AVs could gain around 50% of the market share by 2050.

Another area of research is the analysis of the service side provided by AVs. Automated and autonomous freight transport will expectedly consist of high capacity (e.g., trucks) and small capacity (e.g., vans) vehicles [46]. The small capacity vehicles will be mainly applied in the urban environment for many transportation tasks. Reference [47] presents research on the readiness to entrust one's safety and health while traveling in an autonomous ambulance. As shown, the respondents approach this solution with great caution and uncertainty. As mentioned in Reference [48], the gradual introduction of autonomous ambulance technology through the trial transportation of patients with noncritical injuries may enhance users' trust and lead to the spread of this technology. Currently, in the area of services, innovative solutions are also used in the field of city logistics: EVs, electric cargo bikes (E-CB), new techniques for modeling and controlling traffic [49–51] and AVs are available. Demand-based ICT applications (hardware and software) are also spreading.

The research carried out by the authors of this work showed different tendencies in the perception of the concept of AVs by the respondents (not only active drivers) depending on the grouping variable adopted (age, gender, place of residence and driver's experience). As can be seen from the data presented in Table 1, the majority of the respondents were men (62.2%). The most numerous age group consisted of young respondents aged 19–25—they constituted 47.7% of all respondents. Most people, 35.4%, declared that they came from a city with more than 300,000 inhabitants, and the vast majority of them constituted a group of self-declared drivers, i.e., people holding a driving license, at 87.4%.

The conducted research shows that the belief of respondents regarding the level of autonomy is clearly the highest in relation to level 1. The higher the level of autonomy, the more skeptical both women and men are regarding this solution. The importance of the different types of autonomy is presented in Table 2 and Figure 2.

Table 2. The importance of different types of AVs by respondents based on gender.

Autonomy Level	Woman	Man	Total
Level 1	69	114	183
Level 2	64	104	168
Level 3	61	101	162
Level 4	18	30	48
Level 5	7	11	18
Generally	219	360	579

Summary: Calculating the cardinality; the number of marked cells > 10 Chi^2 Pearson: 17.4178, df = 4, $p = 0.001603$.

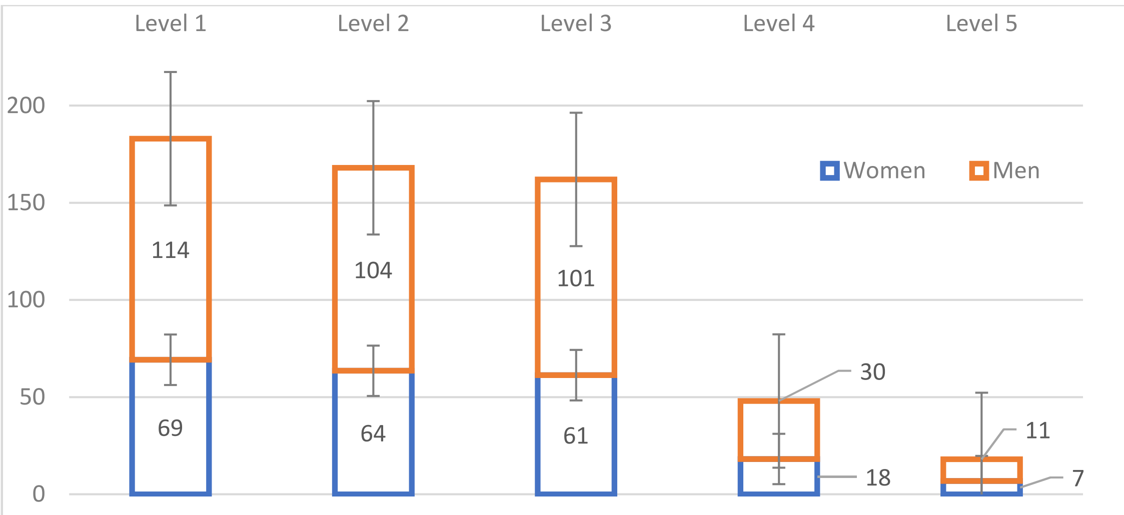


Figure 2. Perception of the levels of autonomy for the AV market among respondents by gender.

In the case of autonomy levels 1, 2 and 3, the significance of the survey is quite high in the opinion of the respondents, because they assess the concept as the most likely form for cars on the market. It should be remembered that these levels apply to standard vehicles supported by autonomous solutions (SVs+).

Respondents positively evaluated the concept of AVs up to level 3, while levels 4 and 5 were rated quite poorly. These are already quite innovative solutions, and in the opinion of the respondents, not very realistic for the automotive market in the near future.

The conducted research also showed that the respondents know the concept of AVs on average—only 30.4% of them have heard and know the concept; while more than half (58.2%) declared that they had heard something about it, and 11.4% of the respondents did not know what the idea was about.

On the other hand, due to the popularity of the progressive introduction of autonomous vehicle solutions on the market, drivers with five years seniority believe that AVs will become popular in more than 20 years. Drivers with 5–15 years of experience, as in the case of drivers who have a longer experience, i.e., 15–30 years as a driver, decided that it would take place in the period of 10–20 years. On the other hand, drivers with the longest experience, i.e., over 30 years, similarly to the youngest ones, said that, in their opinion, the development of AVs would take place in over 20 years (Figure 3).

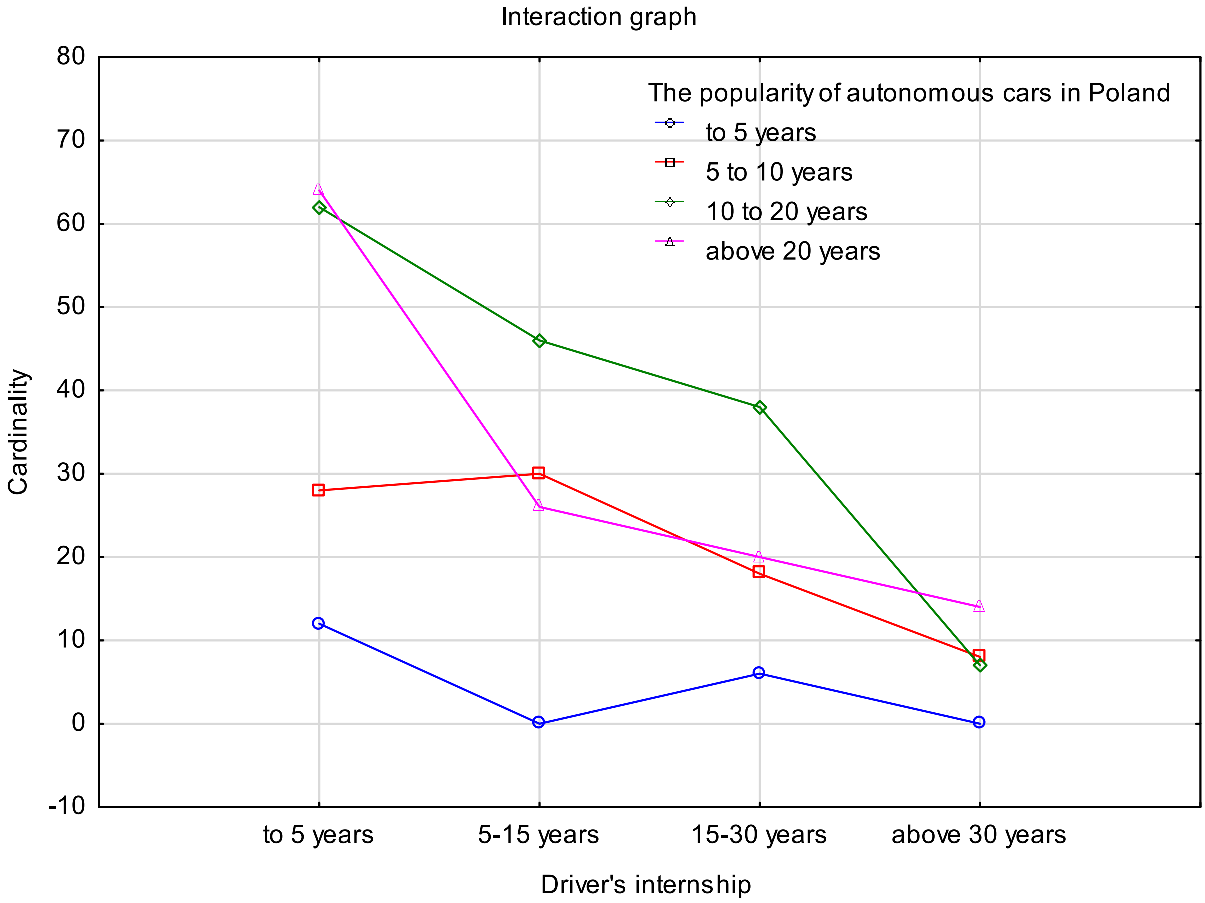
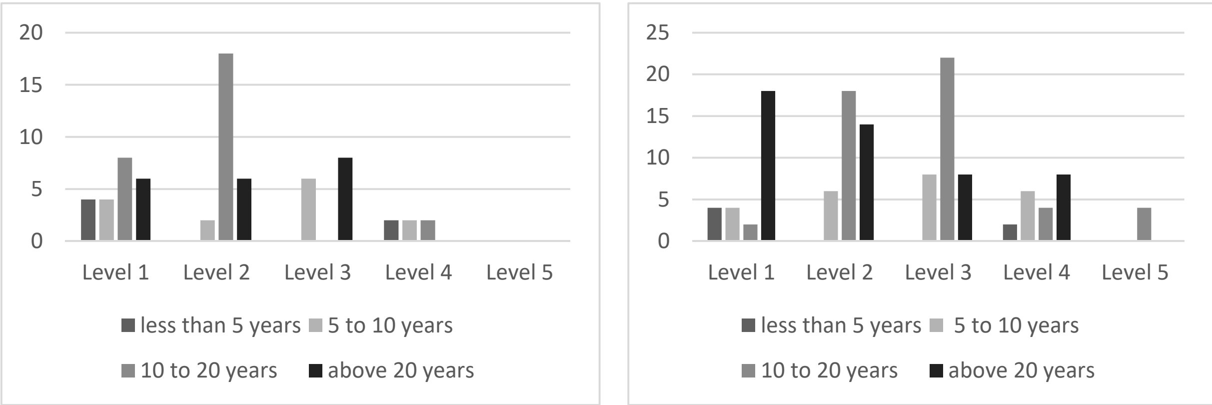


Figure 3. The popularity of AVs in Poland in the opinion of the respondents due to the driver's experience.

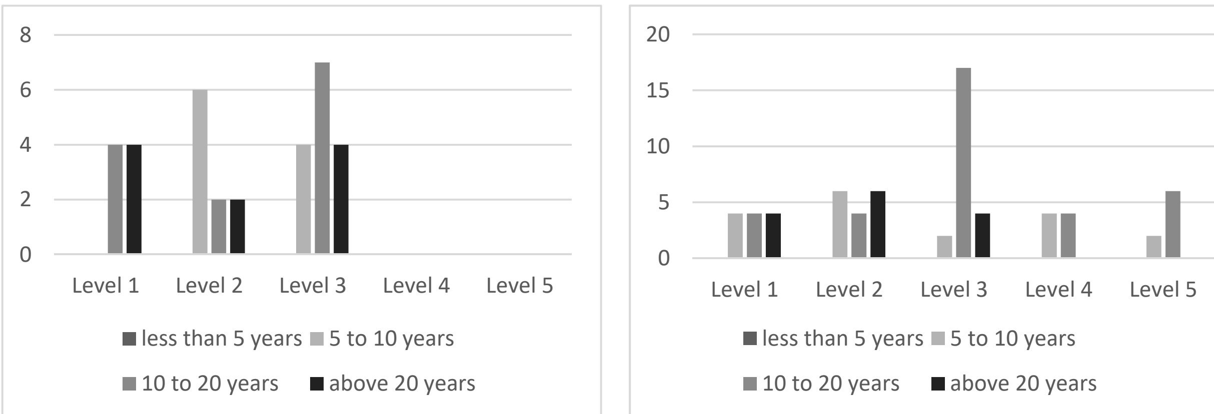
Among the different groups of respondents by age, the concept of the development of the AV market with regard to the level of autonomy was highly diversified (Figure 4a,b). In the 19–25 age group, women were rather unequivocally focused on development over 10–20 years for level 2 of autonomy, while in the same age group, men were not so clearly determined; the majority of indications concerned level 3 (development in the perspective of 10–20 years), the remaining answers were similarly divided into level 1 (development in the perspective of more than 20 years) and level 2 (period of 10–20 years). It should be added that according to women in this age group, the introduction of AVs at level 4 is unlikely, and at level 5, even impossible. In turn, men in this group had a more positive attitude to higher levels of autonomy than women, especially in levels 3 and 4.



(**a**) (**b**)

Figure 4. Perception of the levels of autonomy for the AV market among respondents by gender in the 19–25 age group: (**a**) female; (**b**) male.

The 26–40 age group (Figure 5a,b) indicated the following trends in the perception of levels of autonomy: for women—the most likely spread of AVs was at level 3 (development over the 10–20 years period), while—similarly to the perspective in the previously analyzed age group—the higher levels of autonomy (i.e., levels 4 and 5) were not taken into account at all. It should be added that a large group of women in this age group believe that the introduction of AVs, starting from level 1, will only be possible in 20 years' time at the earliest.



(**a**) (**b**)

Figure 5. Perception of the levels of autonomy for the AV market among respondents by gender in the 26–40 age group: (**a**) female; (**b**) male.

On the other hand, men also mainly see sense in level 3 of autonomy in the period of 10–20 years; however, they are more optimistic than women in this age range in regard to higher levels of vehicle autonomy—indicating a period of 10 to 20 years for perceived development (even for level 5).

The opinions of the respondents in the 41–60 age group were also varied (see Figure 6a,b). Women mainly indicated the 5–10-year development perspective for level 3, while men were less determined, and equally indicated level 1 (over 20 years) and level 3 (development over 10–20 years).

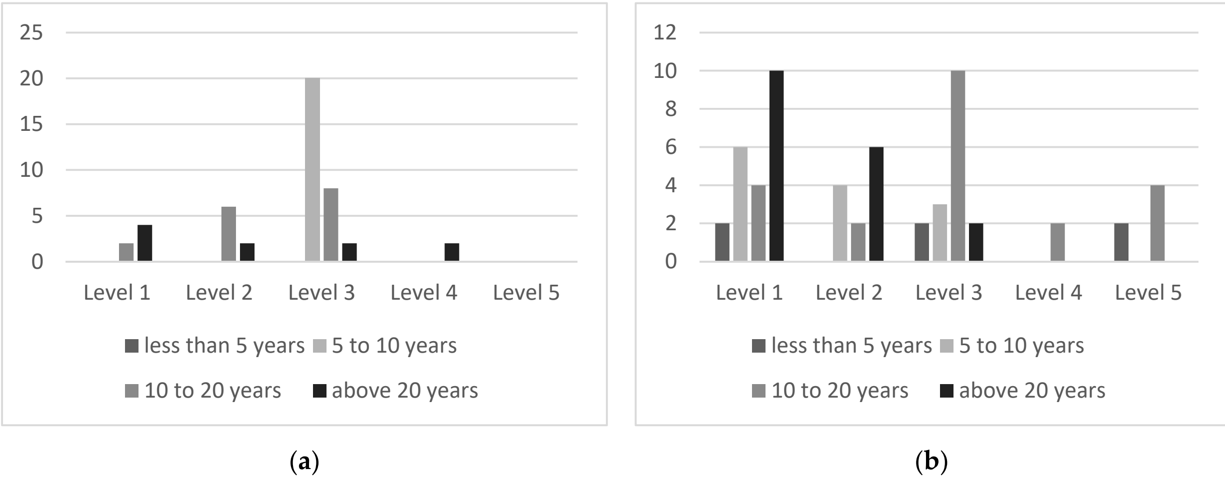


Figure 6. Perception of the levels of autonomy for the AV market among respondents by gender in the 41–60 age group: (**a**) female; (**b**) male.

The smallest age group participating in the study—only 4.3% of the respondents—were elderly people over 60 (Figure 7a,b). In this age group, among women, the indications for level 2 of autonomy (in the period of 10–20 years) were dominant, and levels 3, 4 and 5 were not taken into account at all. On the other hand, men indicated the development perspective for AVs for a period of more than 20 years for level 1, i.e., a small support for a car, which today, among modern cars on the road, perform various functions available on the automotive market (cruise control, reversing or parking assistant, etc.). Thus, levels 4 and 5 were omitted as a potential future trend.

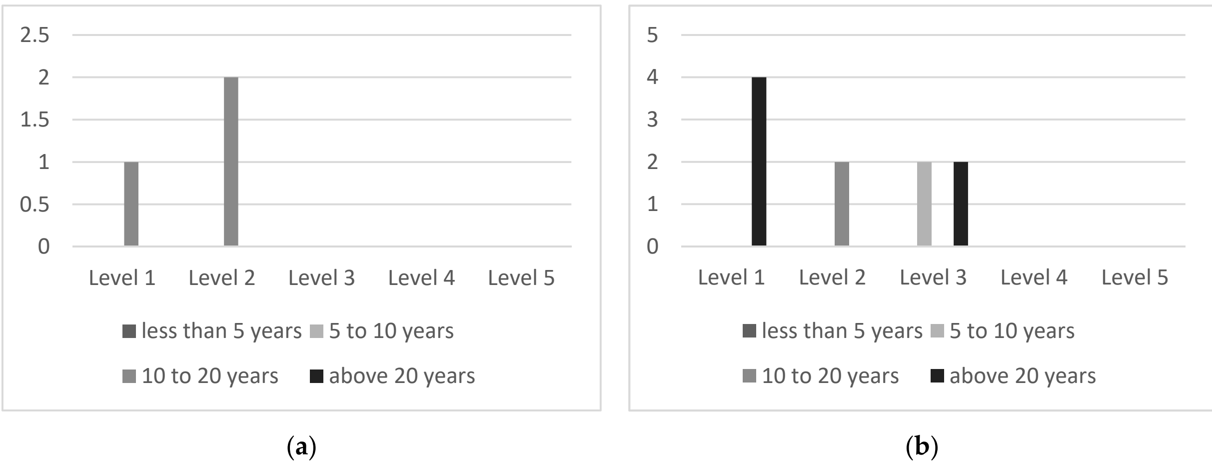


Figure 7. Perception of the levels of autonomy for the AV market among respondents by gender in the age group above 60 years: (**a**) female; (**b**) male.

In further stages of the interpretation of the obtained research results, reference was made to replacing traditional cars with different types of vehicles: HVs, EVs, standard vehicles, but supported by selected functions of autonomous vehicles and, of course, AVs. The analysis shows that among people who know the concept, as many as 68.4% say that AVs will gradually replace the traditional ones. On the other hand, in terms of the automotive market, according to the respondents, HVs will be the most popular in Poland in the coming years (39.4% of respondents' indications) as well as standard vehicles (SVs)—21.2%. It should be added that a similar number of responses were obtained for SVs with autonomous power steering and EVs—18.7% and 18%, respectively. AVs were indicated by only 2.8% of the respondents.

In order to better present the obtained results, in Figures 8–11, in relation to the above analysis, basic descriptive statistics (location measures) are presented including the median, quartiles, minimum and maximum for two variables; the ranges of the variable "place of residence of respondents" are marked on the horizontal axis, while on the vertical axis, individual categories for the variable "vehicle type which, in the opinion of respondents, will be the most popular in the near future" are marked. The survey lists different types of vehicles in terms of their propulsion: standard vehicle—SV, hybrid vehicle—HV, electric vehicle—EV, standard vehicle with autonomous support—SV+ and autonomous vehicle—AV. An autonomous vehicle can be propelled in various ways (SV—petrol or diesel, EV or HV), but in this questionnaire, respondents did not distinguish between the driving method according to its propulsion. Thus, vehicles (SV, EV, HV and SV+) are considered as human-driven vehicles (traditional vehicles), and an AV is to be understood as a self-steering vehicle without human intervention.

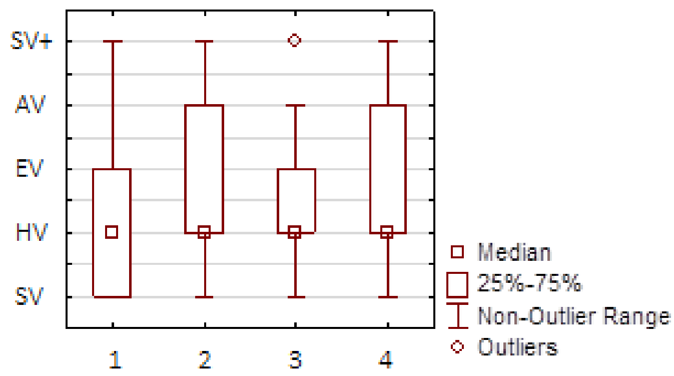


Figure 8. Perception of the popularity of particular types of vehicles among the respondents according to the place of residence: 1—city with more than 300,000 residents; 2—city to 10,000 residents; 3—100,000–300,000 residents; 4—rural areas.

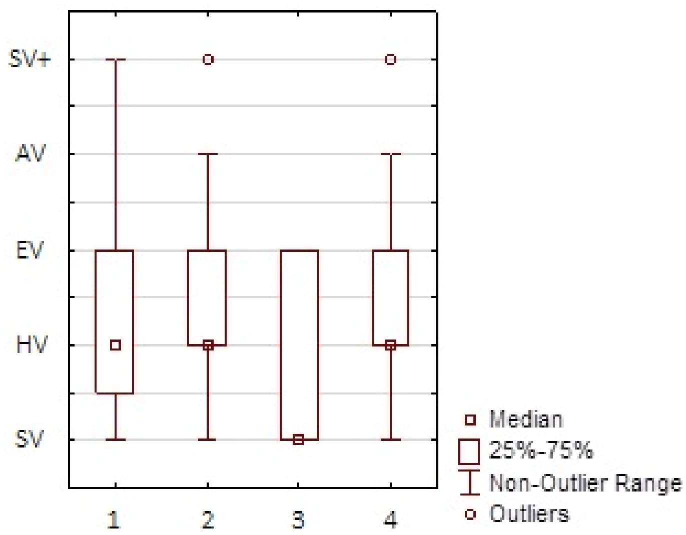


Figure 9. Perception of the popularity of particular types of vehicles among the respondents in terms of the respondent's age: 1—41–60 years; 2—26–40 years; 3—60 years and more; 4—19–25 years.

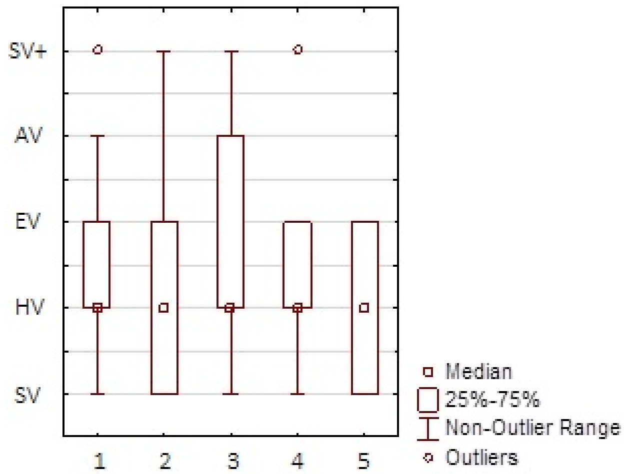


Figure 10. Perception of the popularity of particular types of vehicles among the respondents due to their driving license status: 1—more than 10 years; 2—6 to 10 years; 3—1 to 5 years; 4—none; 5—less than 1 year.

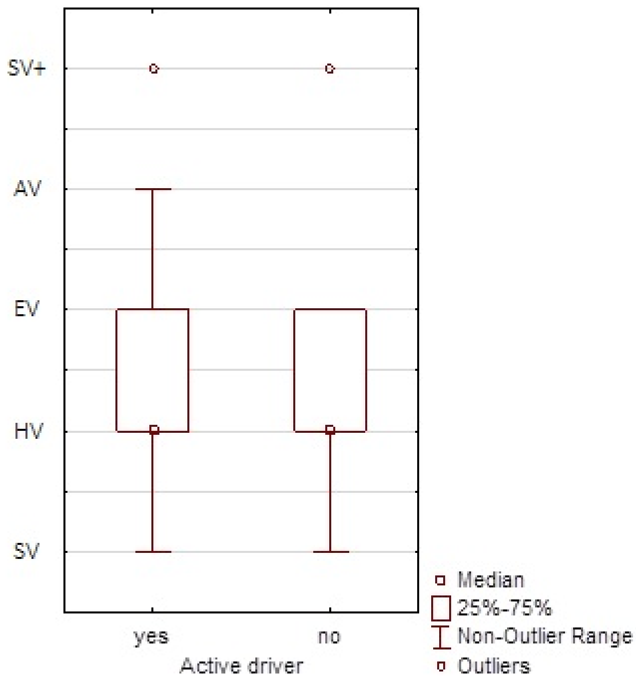


Figure 11. Perception of the popularity of particular types of vehicles among the respondents due to their driver's status.

As shown in Figure 8, over 50% of respondents were living in large cities with more than 300,000 inhabitants, and they mainly indicated HVs, but also SVs and EVs. People living in cities from 100,000 to 300,000 inhabitants—mainly indicated HVs and EVs. On the other hand, people living in smaller cities and rural areas, in addition to HVs, also indicated EVs.

As shown in the data presented in Figure 9, the majority of respondents aged 41–60 indicated mainly HVs, but also SVs+. People aged 26–40 indicated perceptions similar to people from the previous age group, but adding EVs. People in the age group over 60, however, most often indicated the popularity of SVs, also considering EVs and HVs. The respondents from the youngest age group indicated HVs as the most popular in the near future and also mentioned SVs+.

As can be seen from the data presented in Figure 10, the impact of the status in relation to the driving license on the popularity of particular types of vehicles in the near future was marked by the popularity of HVs by all people. For respondents who had a driving license for more than 10 years, they also showed EVs and SVs+. In the case of respondents who had a driving license for 6 to 10 years, they indicated SVs and SVs+. The respondents who had a driving license in the range of 1–5 years showed HVs, EVs and AVs. Among the respondents without a driving license, they indicated the popularity of HVs and EVs. In turn, respondents who had a driving license for less than a year indicated HVs, EVs and SVs.

Among active drivers (Figure 11), the respondents selected HVs and EVs as well as SVs and AVs. In the second group, the respondents selected HVs, EVs and SVs. The above analysis shows that most respondents predicted the greatest popularity in the near future for HVs, followed by EVs. At the same time, a significant proportion of respondents indicate SVs. Based on these studies, it can be concluded that relatively few people are convinced about the technology of AVs in Poland in the near future, and these are respondents who are active drivers.

3.2. Barriers and Challenges in the Field of Autonomous Vehicles

There are also barriers and factors that slow down the large-scale introduction of AVs. Some of them result from the mentality of the society—attitudes, preferences and approaches to using this type of vehicle. It was indicated that a large part of potential users do not feel safe in a vehicle without a driver. Moreover, they are not prepared to give up the freedom and independence that comes with owning and driving their own vehicle. On the other hand, potential users are concerned about the need to control and react quickly in emergency situations, such as a failure of the automation or the vehicle exceeding its functional limits [45].

It is also likely that the infrastructure and the applicable legal regulations (regulating the principles of operation of AVs or insurance regulations) will block the widespread introduction of self-driving cars. It should be remembered that AVs must learn to drive not only in predictable conditions, but also in imperfect and dynamic conditions, in which both human behavior, weather and various other obstacles may create difficult situations on the road. In addition, attention is drawn to the high cost of acquiring such a vehicle due to the complexity of software and cybersecurity, extensive hardware requirements for video systems and the challenges of large-scale network management.

As argued by Shariff et al. [52], the greatest obstacles to mass AV adaptation may be psychological, not technological. If AVs are not widely accepted by the society, road safety cannot be improved and the anticipated benefits for society and the environment cannot be achieved [53].

Adapting AVs to public roads is therefore associated with many challenges. Such vehicles will have to be more integrated with national intelligent transport infrastructures and systems, such as satellite navigation systems in vehicles, traffic signal control systems, information about parking lots, weather forecasts, de-icing bridges, automatic number plate recognition systems or speed cameras for monitoring related applications.

Research carried out by Silberg et al. on technology acceptance, adoption and application of automation technology in vehicles has gained great value in research in the field of transport [54]. They conducted a survey addressed to focus groups in California, New Jersey and Illinois in the USA, asking for their opinion on AVs. It was found that respondents would be more interested in adopting AVs if they received incentives such as autonomous vehicle lanes. In addition, people over 60 and people aged 18 to 25 showed the highest readiness for this type of solution. In contrast, Schoettle and Sivak [55] surveyed public opinion on autonomous and AVs among 1533 respondents in the USA, Great Britain and Australia. The survey found that most respondents were interested in having a fully self-contained vehicle technology, but most respondents said they would not be willing to pay extra for this technology. Respondents in the USA expressed greater concern than those in the UK or Australia regarding data privacy, interactions with self-driving vehicles, learning to use vehicles and operating the vehicle in bad weather.

On the other hand, Underwood [56] examined the opinion of 217 transport experts on automated vehicles. Respondents identified legal accountability and regulation as the most difficult barriers to deploying fully automated vehicles, and social and consumer acceptance was considered the least difficult. Moreover, other recent opinion polls have shown that the general public shows some resistance or a neutral attitude to AV technology [24,45].

The own research conducted by the authors of this study also revealed various barriers that may be key in the perception of the development of the concept of AVs. Further analysis was carried out in the breakdown of respondents by age and gender.

Women aged 19–25 see the greatest barrier in the costs of purchasing such a vehicle (21.9% of responses) and safety issues (17.8%). Women aged 26–40 point to the price (15.8%) and the question of liability in dispute (15.8%), while women aged 41–60 are concerned with the price (26.7%) and safety 14.8%). On the other hand, women over 60, similar to the youngest ones, pay more attention to the price (22.6%) and safety issues (16.1%). The results of this analysis are shown in Figure 12.

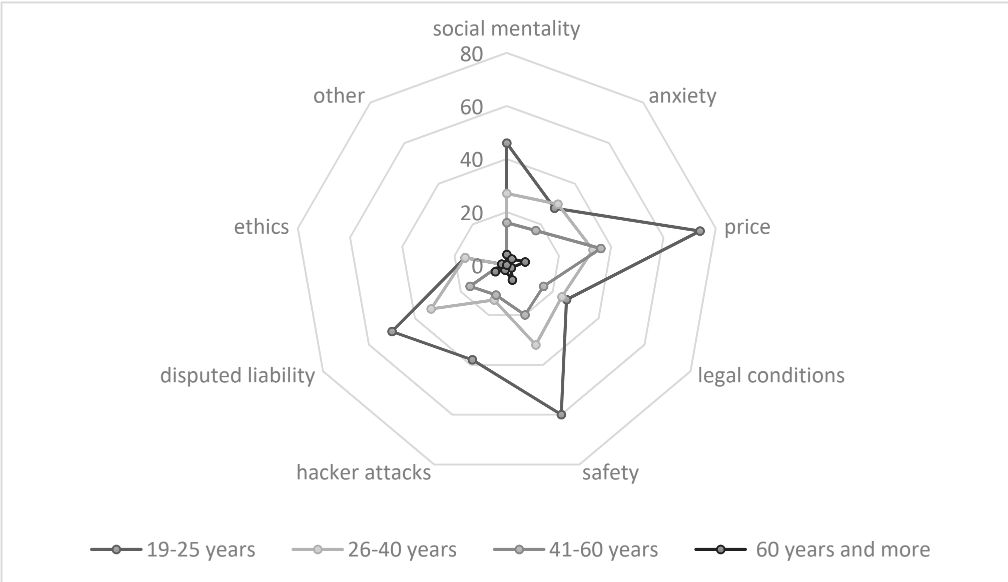


Figure 12. Barriers limiting the positive perception of the concept of AV development in the opinion of women.

In the case of barriers limiting the perception of AV in the opinion of men (Figure 13), it can be noticed that respondents aged 19–25 most often indicated the price and the contentious responsibility (20.3% and 15.9%, respectively). Men in the 26–40 age group see the main barriers in the development of AVs in terms of safety (17.7%) and the cost of buying a vehicle (15.7%), while in the age group of 41–60, the issue that is a more serious barrier concerns the price (21.6%) and potential hacking attacks (17.1%), which other groups of respondents did not pay attention to. On the other hand, respondents in the age group over 60 indicated the price as the main barrier—as many as 50% of respondents in this group expressed their opinion on it, while 25% of respondents were afraid of this solution at all.

From the obtained results, it can be drawn unequivocally that the main barriers are costs, safety issues and disputable liability between road users, in the case of a potential AV driving. Similar conclusions were presented in References [55,57]. In the case of high operating costs of such a system, these concerns are also confirmed by the results of studies presented by Brown et al. [58] and Casley et al. [59] or Shabanpour et al. [60].

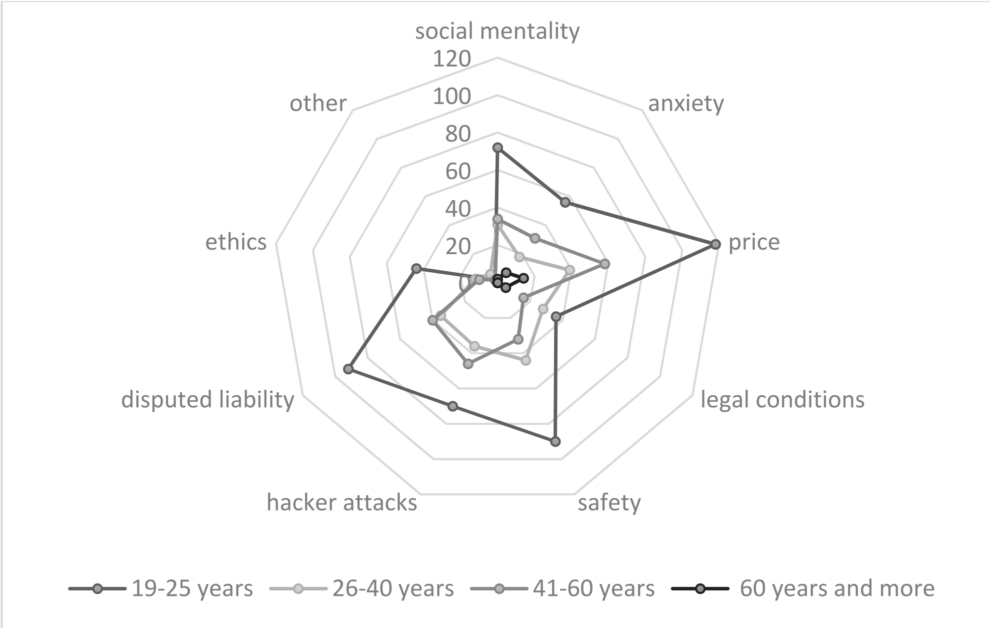


Figure 13. Barriers limiting the positive perception of the concept of AV development in the opinion of men.

3.3. The Future of Autonomous Vehicles in Poland Based on Research Results

Based on the analysis of the literature and our own research, it can be indicated that, in most cases, the widespread use of AVs in road networks would lead to the improvement of road safety in the form of fewer road accidents, as well as savings in energy consumption by vehicles and increased efficiency. Most studies also agreed on potential obstacles to AV adoption, such as legal liability and ethical issues, privacy concerns, cybersecurity and hacking issues, as well as the high cost of vehicles and related technologies.

Research has shown that, in Poland, the process of replacing traditional human-steering vehicles with AVs will be gradual and slow. This process will depend mainly on the adaptation of society to this type of innovation and changes, as well as the wealth of the society. As shown in Reference [8], the introduction of this type of vehicle on a large scale—in the most realistic variant—will take place in the next 20–25 years.

According to the research, most respondents believe that the dominant type of vehicles in Poland in the near future will be traditional human-steering HVs and EVs. The re-search also showed an attachment to SVs (with combustion engines), especially of respondents in the last age group—over 60 years of age.

The most important premises resulting from the analysis of the test results are as follows:

- Respondents positively evaluated the concept of AVs up to level 3 (SVs+), while levels 4 and 5 were rated quite poorly. Moreover, in each age group, there was a greater awareness of the introduction of vehicle autonomy levels among men than among women, who did not show level 5, and level 4 was shown only sporadically.
- Only about 30% of respondents knew AV technology and almost 60% "heard something about this technology". This shows how low the awareness is about innovative solutions in the road transport sector among the respondents.
- The average time of AV introduction in Poland was estimated at 10–20 years and over 20 years.
- Due to the place of residence, the most popular vehicles in the future were indicated by the following: HVs, EVs, AVs and SVs, followed by SVs+.
- Due to the age of the respondents, the most popular vehicles in the future were indicated as HVs, EVs and SVs, followed by AVs and SVs+.

- Due to the length of driving license, the most popular vehicles in the future were indicated by the following, successively: HVs, EVs, SVs and AVs, with SVs+ last.
- In the group of active drivers, the respondents indicated the popularity of HVs, EVs and SVs, and then AVs. On the other hand, HVs, EVs and SVs were indicated as the most popular among inactive drivers.
- Among the main barriers for the introduction of AVs in Poland, the respondents indicated the following: price, safety, disputed liability, social mentality and hacker attacks.

The analysis of the research results shows that the respondents showed great attachment to traditional self-driving, at the same time pointing to the popularity of hybrid, electric and internal combustion engine vehicles. This shows that technology of AVs in Poland is more distant than, for example, in the USA or other, more developed EU countries as well as in the UK. That is why it is so important to promote the benefits of AVs. Activities in the mental sphere are very important—there needs to be promotion of the AV concept and related technologies such as the Smart City, car sharing and other innovative solutions in road transport in urban areas.

4. Conclusions

The article presents our own research on the future of autonomous vehicle technology, obtained as a result of surveys. It summarizes the benefits and barriers to the widespread use of AVs that were seen as the most important in each study. As indicated in the literature in most cases, the widespread use of AVs on road networks would lead to fewer road accidents, increased fuel savings and increased productivity. Most studies also agreed on potential obstacles to AV adoption, such as legal liability, ethical issues, privacy concerns, cybersecurity and hacking issues, as well as the high cost of vehicles and related technologies.

Therefore, it seems that the replacement of traditional cars with AVs will take place gradually and will depend mainly on the adaptation of society to this type of innovation and related changes. Hence, experts and researchers predict that the introduction of AVs on a large scale will take place in the next 20 to 25 years [8]. The degree of advancement of this process, its scale and form will, of course, be different in individual countries—in smaller, well-developed countries with modern infrastructure, such as the Netherlands, AVs may already become widespread in the years 2030–2040. However, in the case of larger and less-developed countries, this may not happen until 2040–2050 or even later. Level 1 and level 2 of autonomy are expected to be introduced extensively, i.e., autonomous functions in commercial vehicles (comprehensive lane assistance and automatic braking and parking functions, adaptive cruise control, blind spot monitoring, etc.), which were previously only available in luxury cars. By contrast, true automation, from level 3 onwards, may prove very limited in most national economies due to insurmountable problems with driver inattention.

Summing up, it can be said that the process of adopting AV technology in Poland will take a relatively long time. Most of the respondents indicated about a 20-year period of adaptation of higher levels of vehicle autonomy.

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