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Vehicle Market Analysis of Drivers' Preferences in Terms of the Propulsion Systems: The Czech Case Study

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Abstract: The automotive sector has been experiencing a rapid development in recent times. Modern trends aim at the progress of so-called sustainable, eco-friendly vehicles, in many cases associated with advanced technologies and assistance systems. It is increasingly common to see cars with electric, hybrid, gas or hydrogen propulsion systems. Such approaches can create a transformation of manufacturing processes towards the growth of new types and fields of technologies and systems in the automotive industry. The manuscript discusses the subject of vehicles with various types of power supply, i.e., propulsion system. The investigation was executed with different respondent groups whereby the analysis was performed predominantly by using two merging criteria such as place of residence and gender of respondents. Following the research conducted, we state that given a variety of variables, the majority of the respondents are convinced that, prospectively, electric and hybrid vehicles in all probability will be the prevailing types of vehicles occurring on the roads of the Czech Republic. However, it is also important to analyze the situation of the current access to energy resources for manufacturing of both kinds of vehicles and, above all, their utilization. Thus, the preferences of drivers are key issues, but it is also necessary to take into consideration the production capacity and investment profitability regarding the purchase of vehicles with modern types of propulsion system.

Keywords: automotive market; drivers' preferences; propulsion system; eco-friendly vehicles; hybrid vehicles; electric vehicles

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1. Introduction

The automotive sector has been experiencing rapid development and changing dynamically recently. Current development trends are aimed at the progress of self-styled sustainable, clean, environmentally friendly vehicles, which are also interconnected with a smart system and assistance system. Cars with an electric, hybrid, gas or hydrogen system are becoming more common. Obviously, such approaches can cause a variation in manufacturing via the implementation of new concepts.

On the global market, it is quite clear that we are on the verge of a new transport era. The pandemic crisis over the years 2019–2021 shook the automotive industry very much around the world, but European car manufacturers were particularly hard hit. This period also influenced the preferences of customers as to the choice of a new vehicle. However, this is not the end of challenges facing the road transport sector, as the upcoming energy crisis is making itself felt more and more strongly in many economic sectors, including the transport sector. Another well-known current problem is climate change, including

fossil fuel consumption and the emission of pollutants into the atmosphere from transport. These challenges need new development trends to overcome them and a new view of the whole society on transport-related issues.

Research suggests that the pandemic generated a sharp drop in international trade over the year 2020, in which supply chains were interrupted, and the transport sector, as the crucial entrepreneur of global trade, suffered the most [1–4]. The sharp decrease in traveling by motor vehicles during the COVID-19 pandemic has resulted in a sharp decline in fuel sales globally. In the United States, over the period of April and September 2020, the mean consumption per month of refined gasoline amounted to 18.12 million gallons (that entails 27% less than the mean consumption per month for this period over the year 2019) [5]. A similar issue occurred all over the world [6,7], which consequently limited transport investments as well as had social consequences in terms of unpaid leave or layoffs of employees in the transport sector. Numerous publications have highlighted the incapability of the tax imposed on gasoline to sustain cost-effective transport because of constant enhancement of the fuel efficiency of vehicles as well as the enormous predicted share expansion of electric vehicles in the near future [8–10]. Due to the significance of efficient and safe transport infrastructure for enterprises, households and the economy as a whole, many research efforts have dealt with the study of various tools and mechanisms regarding revenue generation, their social acceptance and long-term effectivity in terms of obtaining eligible financial resources [11–15]. Social effects of the pandemic are also visible in public transport [16–20] and were reflected in reduced exhaust emissions in cities during the lockdown [21–24].

The issue of pollutant emissions from road transport has a long tradition and is reflected in the successive editions of exhaust gas purity standards known in Europe as "Euro". European emission standards for vehicles were first established in 1970 and, thereafter, the 1st "Euro" standard was established in 1992, which limited the volumes of carbon monoxide (CO), NOx, hydrocarbons (HCs), tailpipe PM and crucial fuel-related indicators, such as content of sulfur [25]. In the literature, readers can find many scientific publications on exhaust gas emissions generated by spark ignition engines [26–33] in various aspects. The papers [26,27] focused on testing exhaust gas emissions from spark ignition (gasoline) engines powered by alternative fuels. The study [26] showed that the appropriate adjustment of the algorithm parameters of the LPG fueling system control allows for the reduction of CO, HC and NO_x emissions. Similar conclusions were drawn by Dziewiątkowski et al. in [27], where emission reduction was also achieved in the case of converting a gasoline-powered engine to CNG. Kriaučiūnas et al. [29] studied the operation of a spark ignition engine fueled with biogas mixtures with volumes of 0%, 20%, 40% and 50% CO_2. It was ascertained that increasing the concentration of CO_2 and use of a constant ignition advance angle increases the combustion time of the burnt mass fraction by 90% and reduces NO_x emissions. Nevertheless, the determination of optimal spark-timing intensifies the brake thermal efficiency and hydrocarbon as well as emission of CO_2 [29]. The possibilities of determining the amount of exhaust gas emissions from vehicles powered by a gasoline engine operated in an urban area were investigated in [32,33]. A lot of scientific papers are focused on the issues of exhaust emissions from compression ignition (diesel) engines [34–39], and in particular on the effect of engine operation parameters on diesel oil [40–43] and various alternative fuels: canola oil and n-hexane mixtures [44], Brown's gas [45], with addition of hydrogenated vegetable oil (HVO), castor oil and biobutanol [46] and others [47]. As shown in the review [34], modern biofuels from 2nd- and 3rd-generation feedstocks can cause a considerable decrease in life-cycle GHG emissions in comparison with conventual fossil fuels and/or 1st-generation biofuels. Practically, 1st-generation or modern biofuels work adequately in current ICEs, both as additive blends with petroleum-based additives and as "drop-in" (i.e., pure) enabling replacements. The main conclusion from the work [34] lies in the fact that in the future, the technologies of heat engines and fuel cells, characterized by high fuel flexibility, high efficiency and very low emissions, will allow consumers to switch to the cheapest and

the most eco-friendly fuel available on markets at that time. Chen et al. [35] conducted research on an oxidation catalyst of several high-performance materials for diesel engines. On the other hand, in the work [36], an investigation of the impact of the physicochemical properties of rapeseed oil and its blending with n-hexane on the time of self-ignition delay was presented. In turn, Makarevičiene et al. [37] performed tests of operational properties and measured the environment-related attributes of diesel oil which contained rapeseed butyl esters. Studies of diesel oil and properties of vegetable oil were presented in [38], and the estimation of emissions of CO_2 out of a compression ignition engine propelled by lignocellulose-derived fuel was carried out in [39]. Droździel [40] was involved in research regarding the start-up process of diesel engines operated in courier vehicles. The work [41] discusses examinations of a power supply system equipped with electromagnetic injectors in the common rail system during simulated operation. On the other hand, Merkisz et al. [42] conducted an examination of thermal energy recovery of exhaust gases by the TEG generator used in urban traffic conditions. Exhaust emission investigation of machines and off-road vehicles in the Czech Republic is analyzed in [48].

Another topic is general pollutant emissions generated by transport. This research was conducted, among others, in [32,49–55]. Road tests in terms of exhaust gas emissions as well as consumption of vehicle fuel depending on specific traffic conditions and type of fuel are presented in [49–51]. The assessment of vehicle energy consumption and emissions from greenhouse gas production in urban areas is presented in [52,53]. Especially in cities, the emissions are burdensome for the inhabitants and are also associated with the occurrence of transport congestion, which was highlighted in the studies [56–58]. In general, the use of alternative fuels of plant origin (biodiesel) or gas has a positive effect on the levels of individual regulated exhaust gas components in relation to diesel oil. This is also confirmed by numerous scientific works in this field [44,45,59–62]. The introduction of electromobility on a large scale would certainly improve air quality in places where vehicles are used, while the electricity to charge electric vehicles must come from renewable energy sources (RESs). The issue of electric vehicle emissions was analyzed in [63,64]. Rievaj, in [65], tried to answer the question whether electric vehicles are actually zero-emission. Studies of the economic and technological approach of renewable and non-renewable energy on the electromobility market in the Slovak Republic and Hungary are presented in [66]. On the other hand, Małek et al. [67], investigated the possibility of charging an electric vehicle from a small photovoltaic (PV) installation. Other studies using PV installations in the Kingdom of Saudi Arabia to charge electric vehicles were presented by Almohaimeed in [68].

Electric vehicles have already been mentioned as the main direction in the development of the automotive industry, but this cannot be called expansion yet. There are still many barriers that hinder the progress of EVs, including: deficiencies in the charging infrastructure, electric vehicle range, vehicle purchase costs, lack of government incentives, customer prejudice, etc. [8,69–73]. For these reasons, internal combustion engine cars are still popular. It is true that the sales of passenger cars powered by a compression ignition engine slowed down (they no longer have a dominant position as of 2015), while in this ranking gasoline engines win. Vehicles with a hybrid system (combustion engine + electric motor) have gained increasing popularity, which is also visible in statistics and scientific research [74–79]. In [74], the optimization and validation of model-based design of propulsion systems in hybrid, plug-in hybrid, electric, as well as fuel cell vehicles are discussed. Furthermore, in the study [75], the consumption of energy of a compression ignition–electric hybrid bus modeled from multiple system modes is presented. Tests of the hybrid-electric system on a Toyota Prius IV car in real city driving conditions are summarized in [77]. Tu et al. [79] outline an interesting study of actual GHG emissions and fuel consumption of hybrid and light gasoline vehicles in local and limited laboratory driving cycles. In practice, hybrid systems save fuel, because most of the route in urban traffic is covered by the electric motor and the internal combustion engine is started sporadically under certain conditions. In addition, the hybrid system allows for recovering energy when braking the vehicle and charging the battery. Many scientific publications are

devoted to energy recovery systems in hybrid vehicles, of which it is worth mentioning, for example, [80–82]. Very good effects of vehicle braking energy management are also achieved in electric vehicles [83–85].

The trends presented above can also be seen in the conducted surveys discussed in the literature [86–90]. In 2011, Carley et al. [88] found out that, considering the battery-related concepts and technologies and public opinion, currently, the overall stated intention to lease or purchase EVs is poor. However, in another study from 2017 presented in [89], the intention to purchase plug-in vehicles among respondents increased compared to 2011. The popularity of plug-in hybrid (electric) vehicles is driven above all by perception of consumers of the shortcomings of EVs [86,88,90,91]. It turns out that respondents interested in electric vehicles are usually well educated, have owned conventional hybrids and are sensitive to environmental protection [86,89,90,92]. The main barrier to the establishment of plug-in hybrid and electric vehicles lies in the fact that customers tend to resist advanced systems and technologies regarded as unproved and alien [93].

Summing up the considerations on the direction in which the passenger car market will go, it can be stated that spark ignition combustion engines are going to play a dominant role in the future, and the departure from the compression ignition engine will be more and more pronounced. Plug-in hybrid vehicles will also make their presence felt more and more strongly. Due to the various limitations highlighted above, electric vehicles will enter the market more slowly, especially in Central and Eastern Europe, where some issues with the development of vehicle charging infrastructure emerge. Problems with the infrastructure are related to, above all, the outdated power grid, a very small number of chargers at fuel stations and the lack of appropriate support programs.

In light of the changing situation on the automotive market, there is a need to analyze the preferences of drivers as to the choice of the propulsion system of modern vehicles. This article discusses the findings of a survey carried out in the Czech Republic in terms of drivers' preferences on the used propulsion system of passenger vehicles in the near future. The key purpose of the work consists in determining the expectations of drivers in relation to motor vehicles in the Czech Republic. The layout of the work is as follows: Section 2 briefly describes the Czech Republic, the most pertinent macroeconomic indicators and the general situation in the road transport sector including transport infrastructure. The research material and the methods used in the article are summarized in Section 3. Thereafter, the research findings are shown and an accompanying discussion is given in Section 4, while Section 5 presents the summary of the most important outcomes from the research conducted.

2. A Brief Description of the Automotive Market in the Czech Republic

The Czech Republic is an inland country situated in Central Europe in the northern and eastern hemisphere. Its area is 78,866 km^2. In terms of territory, the Czech Republic ranks 21st in Europe and 113th in the world. It shares borders with four countries as follows: Germany (818.9 km), Poland (795.7 km), Austria (460.3 km) and Slovakia (251.7 km); in total, the entire border length is 2326.8 km. In 2022, the population was 10,525,739 (of which 50.7% were women and 49.3% were men), whereby the Czech Republic has an above-average population density in Europe—134 inhabitants/km^2—which ranks it 12th in Europe. The capital is Prague, which is also one of the regions [94].

As for the population composition, children aged 0–14 make up 16.1% of the total population (which is a total of 1,691,760, out of which 866,322 are boys and 825,438 are girls), persons aged 15–64 make up 63.5% of the total population (which is 6,684,359 in total, of which 3,416,851 are men and 3,267,508 women) and seniors aged over 65 years of age make up 20.4% of the total population (which is 2,148,048 in total, of which 903,375 are men and 1,244,673 are women). The mean age of the population is 42.7 years, with women slightly older at 44.1 years than men at 41.2 years, and in 2022, the total fertility rate was 1.83 children per woman [94].

At the moment, the Czech Republic has approximately 3800 municipalities of rural areas with less than 500 inhabitants, a total of 609 settlements with the designation of city, of which 127 cities have a population of more than 10,000, of which 18 cities have more than 50,000 inhabitants—out of which 13 are small cities with a population of 50,000–100,000, 2 are medium-sized cities with 100,000–300,000 inhabitants and 3 are large cities with over 300,000 inhabitants (including one metropolis, with a population of over 1,000,000, which is the capital Prague). One quarter of the country's population lives in the 10 biggest cities [94].

According to the World Bank, the Czech Republic economically belongs to the group of the thirty-one richest states across the world with the highest financial income [95]. Compared to other states, it has a very small share of the population living under the line of poverty. It shows low inequality among the richest and poorest residents as well, and almost a balanced level of distribution of wealth among the residents. The unemployment rate has been relatively low for a long period and is below the mean of developed states.

It is a part of the European Union, the North Atlantic Alliance, the United Nations, the World Trade Organization, the Organization for Economic Cooperation and Development, the World Bank, the International Monetary Fund, the Council of Europe, the European Customs Union, the Organization for Security and Cooperation in Europe, the Schengen Area, the Visegrad Group, the European economic area, etc. [96].

The Ministry of Transport is the central entity of transport administration in the Czech Republic. Its transport network is very developed. For historical reasons (the mercantilist policy of the Austrian and Austro-Hungarian empires), this mainly concerns railways and roads of the 1st and 2nd classes. The highway network has been in existence since the 1960s and is still being constructed. High-speed railway lines are just in sight as well. On the other hand, public administration in the Czech Republic emphasizes urban and suburban public transport. That in Prague, being the only area in the country to use the metro system, is rated as one of the best in Europe. Once completed, the D1 highway will entail a backbone which will connect Prague, Brno and Ostrava with Poland (Katowice direction). The already completed roads are as follows: the D2 highway connecting Brno and Bratislava, the D5 highway connecting Prague, Pilsen and Germany (Nuremberg direction), the D8 highway from Prague via Ústí nad Labem to Germany (Dresden direction), the D10 highway (Prague–Turnov) and the D46 highway (Vyškov–Olomouc). The D0, D3, D4, D6, D7, D11, D35, D48, D49, D52, D55 and D56 highways are in various stages of construction. The permitted velocity on the highway is 130 km/h max. and motorists pay a toll for using it. Overall, the road transport network length in 2021 was 55,837.6 km, of which the European type E road network was 2629.4 km long, highways were 1346.2 km long and 1st class roads were 5799.6 km long.

In 2021, the overall number of passenger cars on Czech roads was 6.29 million. A chart of the overall number of passenger cars in the Czech Republic in 2021, depending on the type of propulsion system used, is shown in Figure 1.

In total, 206,876 new passenger cars, 19,660 light commercial vehicles, 1006 buses, 8679 trucks and 22,019 motorcycles were registered in the Czech Republic. In regard to the type of fuel in newly registered passenger cars, gasoline-powered vehicles were the most represented at 68.06% and diesel-powered vehicles—24.70%. Additionally, 23,074 passenger cars with a hybrid-electric system were registered (+82% year-on-year), of which 3736 (+89%) were plug-in hybrids. In general, in regard to the number of registered passenger vehicles with an alternative propulsion system, it rose to 28,830 vehicles from 18,507 vehicles in the year 2020 (+56%).

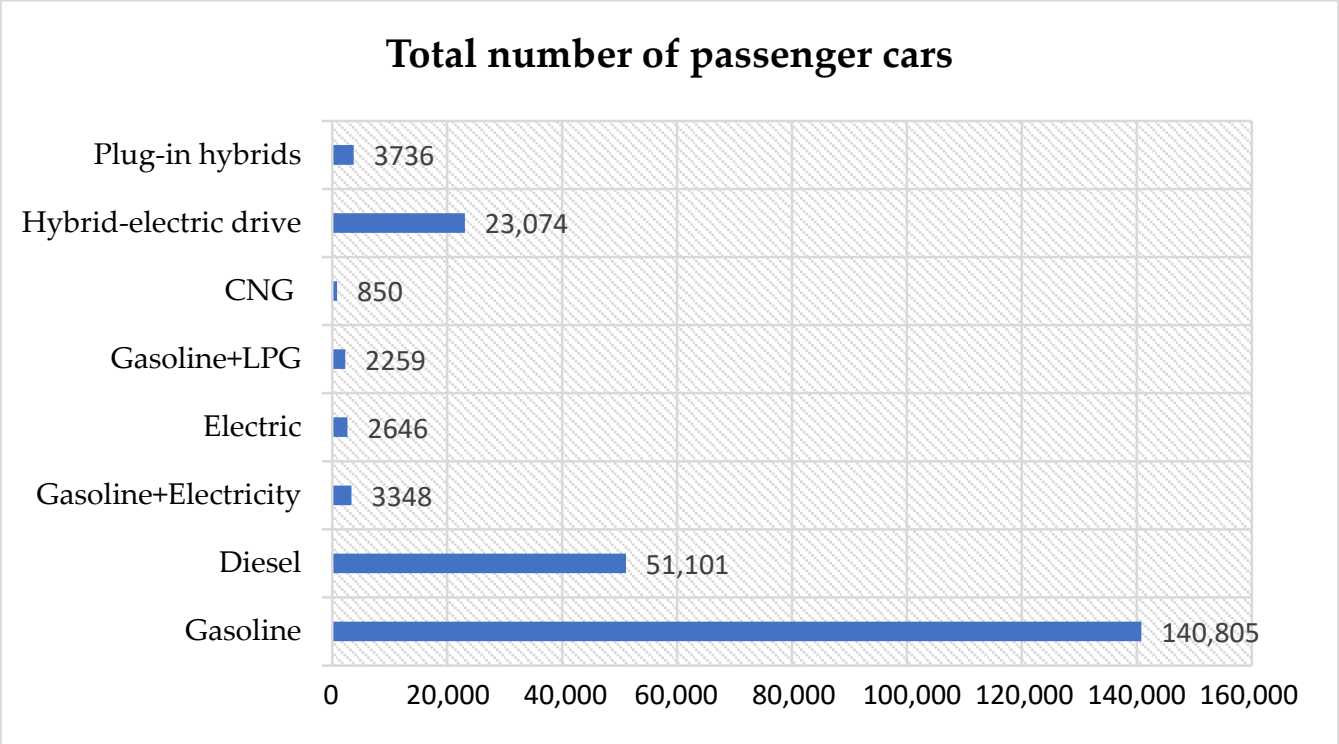


Figure 1. Total number of passenger cars in the Czech Republic in 2021.

3. Materials and Methods

3.1. Study Design—The Choice of the Research Method and Study Area

The research was conducted in 2022 using the diagnostic survey method, in accordance with the adopted qualitative approach, which allowed us to achieve the assumed research goals. Their purpose was to illustrate the phenomenon of preferences on the type of vehicle chosen by drivers and other users of passenger cars in the Czech Republic, and above all, declarations of what affects this type of choice and what kind of factors increase the attractiveness of solutions. The selected research method allows for the collection of a variety of information in the field covered by the study, from many different perspectives, and this in turn makes it possible to obtain information about the subjective and objective opinions and attitudes of respondents [97,98].

A structured survey questionnaire was used as a research tool, so that it was possible to properly process the obtained primary data.

The block diagram of the completed study is shown in Figure 2.

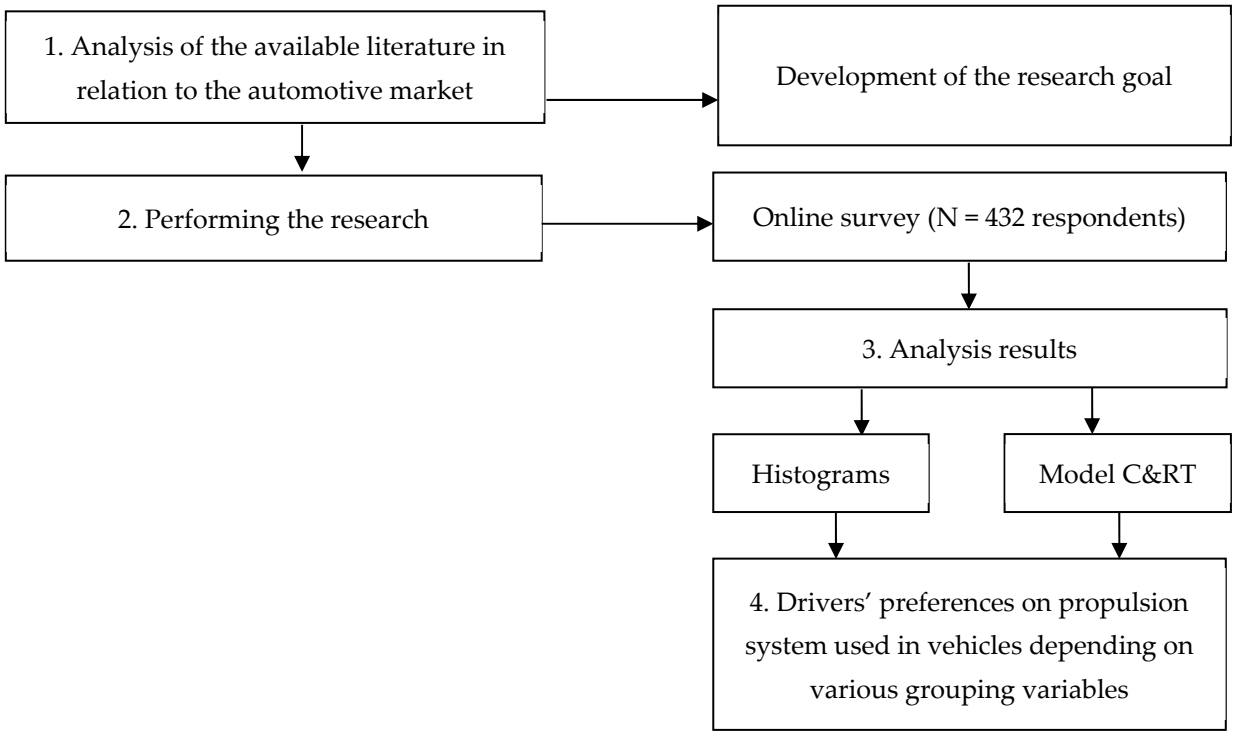


Figure 2. Flow chart of the methodology of the overall study.

3.2. Survey Questionnaire as a Research Tool

As already mentioned above, the study used an original structured questionnaire as a research tool. The questionnaire was distributed via the Internet—Google Forms. It should be added that the survey was anonymous, and the respondents voluntarily decided to complete it, and were also informed about its purpose and how to complete it correctly.

The survey questionnaire used in the research consisted of two parts, i.e., metric and substantive. It also contained an introduction in which the respondents were presented with the aim and assumptions of the survey, as well as a short instruction on its correct completion. The first part of the questionnaire allowed us to obtain information about the socio-demographic characteristics of the respondents. The analyzed grouping variables were such descriptive characteristics of the respondent as: gender, age or place of residence. The second part of the questionnaire, on the other hand, made it possible to provide information in the area of the research problems. It contained closed, single-choice questions. Respondents were mainly asked what types of vehicles they prefer, what levels of autonomy in solutions they see as innovative solutions in the future, and when this development will take place.

3.3. Research Sample

The research sample consisted of 432 people—residents of the Czech Republic. Purposeful sampling was used as one of the non-random sampling methods to select the research sample. The premise for using this method of selecting the sample for the study was the fulfillment by the respondents of the criteria defining the assumed categories of grouping variables, which were placed in the metric part of the questionnaire. In addition, it should be noted that the purpose of using such a research sample selection method is to create a sample as close as possible to a representative sample [99].

The structure of respondents in the obtained research sample, according to gender, was as follows: 108 women (25%) and 324 men (75%). When analyzing the distribution of another grouping variable, i.e., place of residence, it was found that in the structure of people participating in the study, the largest number of respondents lived in small towns (up to 100,000 inhabitants)—more than half of the respondents—261 (60.4%). There

were 54 inhabitants in rural areas (12.5%), 27 inhabitants of medium-sized towns (from 100,000 to 300,000 inhabitants) (6.3%) and inhabitants of the largest cities—over 300,000 residents—accounted for 20.8% of all respondents (90 people).

3.4. Data Analysis

Data analyses were carried out using Statistica 13.3 statistical processing software and an Excel 2013 spreadsheet. Graphical, descriptive and tabular methods were used to present the obtained test results.

Due to the fact that the qualitative approach was adopted in the research, it was necessary to use appropriate methods that would enable a reliable and unambiguous interpretation of phenomena [100]. Therefore, mainly descriptive methods were used, as well as one of the methods of statistical data analysis—the so-called analysis using classification trees.

Table 1 presents the detailed characteristics and profile of the respondents participating in the study, in particular, it includes basic information about: research, methods and tools as well as sample selection criteria that have been implemented for the purposes of this publication.

Table 1. Basic characteristics of the scope of the research conducted in the Czech Republic.

Description	Characteristic
Research goals	- analysis of primary data allowing for segmentation of drivers and users of passenger cars due to specific determinants determining their behavior in the use of various propulsion systems used in vehicles, - identification of drivers' preferences in terms of changes and challenges facing the vehicle market
Research object	drivers and users of passenger cars
Type of research	qualitative research
Research method and technique	online survey (Google Forms)
Research tools	proprietary survey questionnaire
Selection of units for research	non-random, targeted
Sample selection criteria	individual drivers and users of passenger cars, a group of respondents differentiated by gender, age and place of residence
Sample size	432 people
Spatial scope	the Czech Republic
Time frame of the research process	January–June 2022

4. Results and Discussion

The main emphasis in this study, conducted on the basis of a structured research survey, was placed on the analysis of drivers' preferences (current or potential) in the Czech Republic regarding the propulsion system used in vehicles. The following vehicles were included: standard vehicle (SV), hybrid vehicle (HV), electric vehicle (EV), autonomous vehicle (AV) and standard vehicle supported by autonomous solutions (SV + A).

Two grouping variables were used to analyze the obtained results, namely gender and place of residence. These variables were chosen for several reasons. Firstly, it was assumed that women (as drivers) may have slightly different attitudes and preferences in relation to particular types of vehicles due to the source of propulsion used in them—it seems that they may focus more on aspects related to habit and safety; they may also be wary of the more advanced functions, tasks or procedures associated with modern systems used in modern vehicles [101–103]. On the other hand, it is assumed that men may be more open

to changes and technological novelties; therefore, they may place more trust in vehicles with more innovative solutions—such as, for example, electric or autonomous or hydrogen cars [104,105]. Ziegler [106] came to a similar conclusion, stating that men show higher declared preferences for alternative energy sources and propulsion technologies.

In the conducted research (Figure 3), it turns out that women believe that in the near future the dynamic development of vehicles will mainly concern those with a hybrid system (HVs), but the development of standard cars (SVs) will also be maintained, especially those supported by autonomous solutions (SVs + A). Men believe that, similarly, there will be mainly hybrid vehicles (HVs), but also those of a traditional character (SVs).

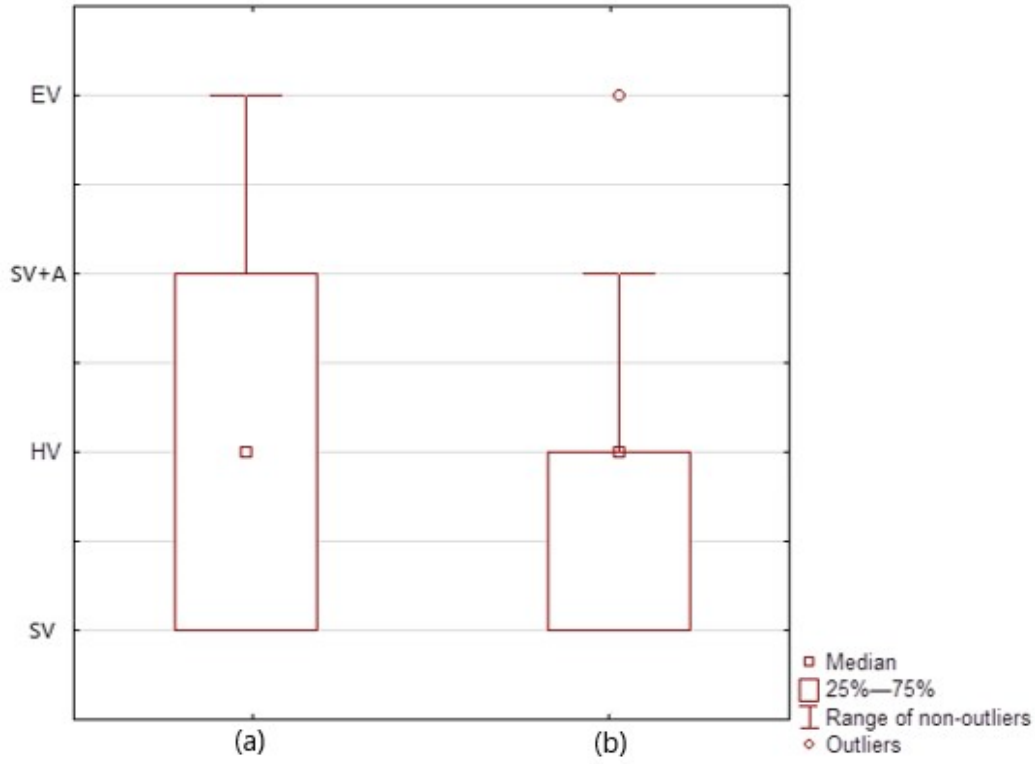


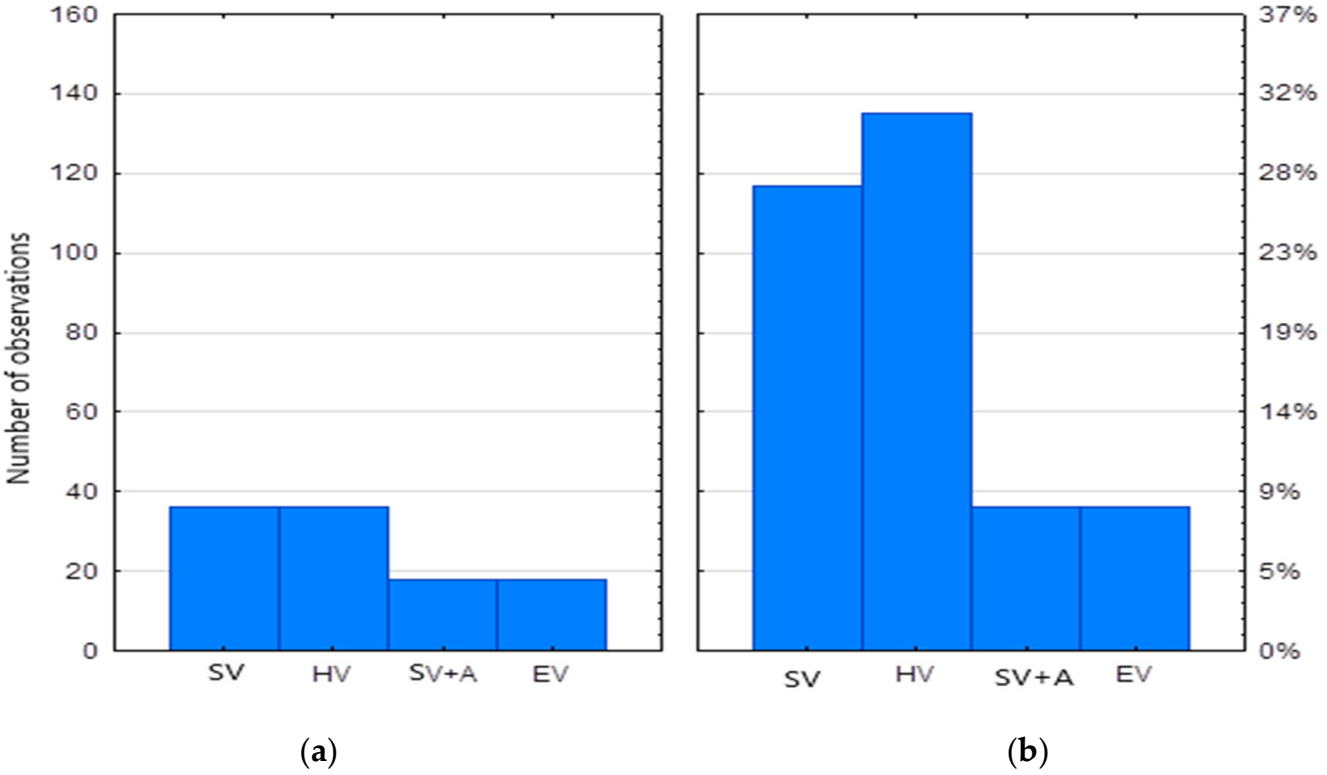
Figure 3. Popularity of car types by source of propulsion in the near future—analysis by the grouping variable "gender": (**a**) women; (**b**) men. Abbreviation: electric vehicle (EV), standard vehicle supported by autonomous solutions (SV + A), hybrid vehicle (HV), standard vehicle (SV).

However, taking into account the second grouping variable used in the conducted analyses, i.e., the place of residence, it seems that it may have a significant impact on the perception of the popularity and universality of vehicles based on individual power sources, which may result from the number of kilometers traveled (to work, for shopping), but also from the availability of services or infrastructure.

In the first phase of the procedure used in the research, the perception of respondents regarding the popularity of particular types of vehicles, distinguished by the source of propulsion, in the near future was examined. The obtained results are summarized in Figure 2 (popularity of car types by source of propulsion in the near future—analysis by the grouping variable "gender") and Figure 4 (popularity of car types by source of propulsion in the near future—analysis by the grouping variable "place of residence").

According to the information obtained, both in relation to women (Figure 4a) and men (Figure 4b), there is a preponderance of statements regarding the greater popularity of standard and hybrid vehicles than other types of vehicles in subsequent years. Linzenich et al. showed that, currently, the vast majority of drivers prefer conventional fossil fuels, which in turn determines low consumer demand for alternative fuels [107]. Shin et al. [108] in their research concluded that a hybrid vehicle is preferred to a similar degree as a

standard vehicle, while other types of vehicles are less preferred alternatives by current or potential drivers.



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

Figure 4. Popularity of car types by source of propulsion in the near future—analysis by the grouping variable "gender": (**a**) Female; (**b**) Male.

It should be added, however, that in the case of men this advantage is significant. In addition, men even see the prospect of a greater prevalence of hybrid vehicles than standard ones.

A similar analysis was carried out for the next considered grouping variable, which is the place of residence (Figure 5).

When analyzing the information presented in Figure 5, certain trends can be observed. People living in rural areas (Figure 5-upper left side) trust, and consequently see, a future only for standard (SV) and hybrid (HV) vehicles. As mentioned earlier, this may result from a lack of knowledge, but also from caution or perception of too high a risk associated with more modern vehicles (EVs, AVs or even SVs supported by autonomous functions) or from the awareness of the lack of appropriate infrastructure for this type of vehicle in the near future. A similar approach can be seen among respondents living in medium-sized cities (from 100,000 to 300,000 inhabitants), but they equally see the popularity of not only SVs and HVs, but also EVs, in the coming years (Figure 5-lower left side).

A completely different approach to the analyzed problem is declared by the inhabitants of small towns (up to 100,000 inhabitants) and large cities (over 300,000 inhabitants). In the first case (Figure 5-upper right side), inhabitants of small towns see the greatest prospects in the near future in hybrid vehicles. This may be due to the current economic situation, i.e., higher inflation, and consequently higher fuel prices. Respondents from this group may cover a large number of kilometers in connection with commuting to work, universities or shopping in larger cities; hence, they focus more on hybrid vehicles that are cheaper in their opinion. However, according to these respondents, standard vehicles will not lose their popularity in the coming years either. Interestingly, these people see better prospects for standard cars supported by autonomous functions than for electric cars. This, in turn, may result from rising electricity prices. The human (psychological) factor may also be

important here—as stated by Rauh et al. [109] there is a so-called range anxiety, i.e., the psychological perception of the distance that an EV can reach. When using electric vehicles, some drivers, especially less experienced drivers, experience behavioral, cognitive and emotional range anxiety [110,111]. Among the potential reluctance towards vehicles with this type of propulsion system, apart from the limited range, researchers also point to the fact that they are often perceived as vehicles with longer refueling/charging times [108].

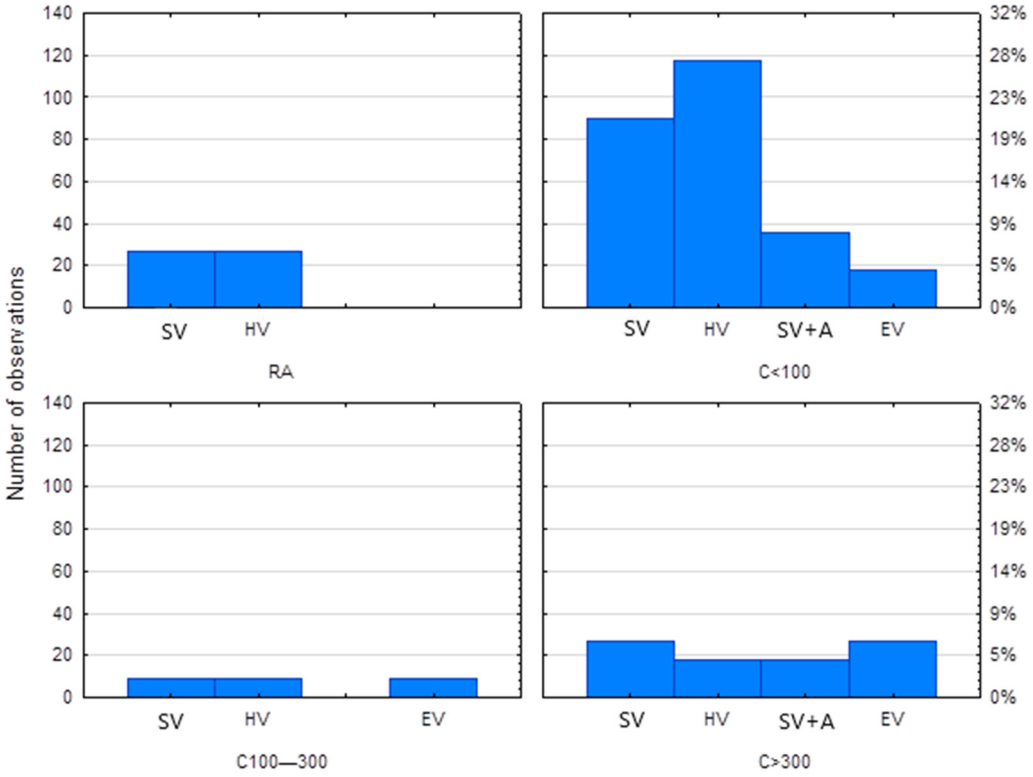


Figure 5. Popularity of car types by source of propulsion—analysis by the grouping variable "place of residence". Abbreviations: RA—inhabitants of rural areas; C < 100—inhabitants of small cities (up to 100,000 inhabitants); C100–300—inhabitants of medium-sized cities (from 100,000 to 300,000 inhabitants); C > 300—inhabitants of the largest cities—over 300,000 inhabitants.

On the other hand, respondents living in large cities (Figure 5-lower right side), on the market of vehicles used by modern drivers, see the best prospects for standard vehicles, on a par with electric vehicles. They further believe that hybrid and SV + A cars will enjoy slightly less interest in the future.

The obtained results are partially consistent with the results of the research described by Khan et al. [112]. They found that households located in cities with longer commutes (to work, school, etc.) are more likely to choose hybrid electric vehicles. Indeed, they can provide an economical alternative to meet additional travel needs. Similar conclusions were also reached by Ščasný and his team [113] after carrying out research in Poland—in turn, according to them, electric vehicles are much less preferred than conventional cars. However, Axsen and Kurani [86] obtained results from a survey that show that across the higher and lower price scenarios, a majority of consumers indicated a PHEV as their next new vehicle. Hence, a smaller percentage of respondents chose an HEV or a conventional vehicle, and only a few percent indicated an EV.

In addition, in the next part of the research procedure, one of the data mining methods—classification and regression tree (C&RT)—was used to classify the set. This is one of the methods of non-parametric discrimination that is increasingly used in scientific research. This is because the currently noticeable increases in the amount of information and the volume of databases are causing an equally rapid increase in the need for their analysis. The aim of

this method is to group and divide objects in terms of distinguished features. It enables the automatic search for patterns and dependencies in large datasets, organizing them into compact models. Considering the above, data mining techniques are now widely used in the analysis of various marketing data, such as market segmentation and selectivity studies.

The chi-squared automatic interaction detector (CHAID), proposed by Kass [114], is one of the oldest classification tree methods (according to Ripley [115], the CHAID algorithm is the successor to the THAID algorithm by Morgan and Messenger [116]). CHAID does not build binary trees (i.e., it builds trees in which more than two branches can emerge from nodes) and does so using a simple algorithm that is used to analyze large datasets. The name comes from the name of the basic (non-binary) tree-building algorithm, which in classification problems (where the dependent variable is inherently categorical) relies on the chi-square test as a criterion for determining the next best split at each step in regression-type problems (continuous dependent variable) in which the program calculates the value of the F-test. First, qualitative predictors are created from quantitative predictors by dividing the distribution into a certain number of categories so that each category includes approximately the same number of observations. With categorical predictors, the classes are already "naturally" defined. Since the algorithm often creates effective crosstabs (e.g., when the dependent variable is classified with multiple classes and the independent variables are also categorical with multiple classes), as mentioned earlier, the algorithm is popular in market research. Both methods (CHAID and C&RT) create trees in which each node (except leaves) contains a split condition, and the goal is optimal prediction (quantitative dependent variable) or classification (categorical dependent variable). Both types of algorithms can be applied to regression and classification problems.

Figure 5 shows the dependence of the popularity of individual types of propulsion system used in passenger cars on dependent variables such as the level of vehicle autonomy, age of the driver, place of residence and the time when these cars will be popular in the near future.

The data presented in Figure 6 show that rules have been created indicating the separation of groups of drivers who perceive the prospects for the development of the vehicle market in a different way, especially those of a sustainable, ecological nature, in the Czech Republic.

In the first node (ID = 1), n = 108 cases (i.e., women drivers) were identified in the entire dataset. The bars for the SV and HV categories are of similar size, which means that the cases for which the values of the dependent variable meant traditional and hybrid vehicles prevailed in our set. Hence, in the next step, an attempt was made to separate the cases, i.e., to create such rules that would predict them well. The first variable that takes part in the division is the type of level of autonomy in the declared types of vehicles. The women who chose Level 1 definitely combined this fact with standard vehicles. Women who chose Levels 2 and 3 believe that the popularity of cars will be related to hybrid vehicles (HVs).

As for the other classification divisions, nodes ID = 6 and ID = 7 (36 cases in total) meant a separate group of drivers who foresee the popularity of cars with a standard system (gasoline or diesel engine) over the course of 10–20 years (only standard vehicles) and over 20 years (here, preferences referred to standard and hybrid cars) and they are mainly women aged 41–60. In turn, the ID = 5 node separated women aged 26–40, who also see the future of cars in relation to these standard solutions.

In regard to node ID = 8, women living in medium-sized cities (100–300,000 inhabitants) were singled out here, who believe that the future of cars is solutions with an electric propulsion system (it should be noted that these are the respondents who connect this fact with Levels 2 and 3 of solution autonomy). In turn, women living in small cities (up to 100,000 inhabitants) see the future of cars in the 3rd level of autonomy and hybrid vehicles (ID = 10), while those who chose the 2nd level of autonomy pointed to standard cars supported by autonomous solutions (ID = 11).

Figure 6. C&RT classification tree for the dependence of the popularity of individual types of systems used in passenger cars in the opinion of women on such dependent variables as the level of vehicle autonomy, age of the driver, place of residence and the time when these cars will be popular in the future.

According to the information presented in Table 2, as far as women are concerned, six rules were created, according to which the probability of indicating a specific type of propulsion system is the highest for women who chose the development of standard systems in the perspective of more than 20 years (probability was 66.7%)—ID = 7, the choice of hybrid cars with the 3rd level of autonomy by women living in small towns (probability is 66.7%)—ID = 10 and in the case of ID = 11, the indication of traditional solutions with autonomous support (the probability of this indication was 66.7%).

Table 2. Results in terminal nodes for the dependent variable: popularity of car type in the near future in the group of women. Model: C&RT.

	Class HV	Class SV + A	Class SV	Class EV	Gain	=v1/v5	=v2/v5	=v3/v5	=v4/v5
6	0	0	9	0	9.00000	0.0%	0.0%	100.0%	0.0%
7	9	0	18	0	27.00000	33.3%	0.0%	66.7%	0.0%
5	0	0	9	0	9.00000	0.0%	0.0%	100.0%	0.0%
8	0	0	0	9	9.00000	0.0%	0.0%	0.0%	100.0%
10	18	0	0	9	27.00000	66.7%	0.0%	0.0%	33.3%
11	9	18	0	0	27.00000	33.3%	66.7%	0.0%	0.0%

Similarly, in the case of men drivers, the data presented in Figure 6 show the rules created indicating the separation of groups of drivers who perceive the prospects for the development of the vehicle market in a different way.

The data presented in Figure 7 show the rules created indicating the separation of groups of drivers who perceive the prospects for the development of the vehicle market in a different way, especially those of a sustainable, ecological nature, in the Czech Republic.

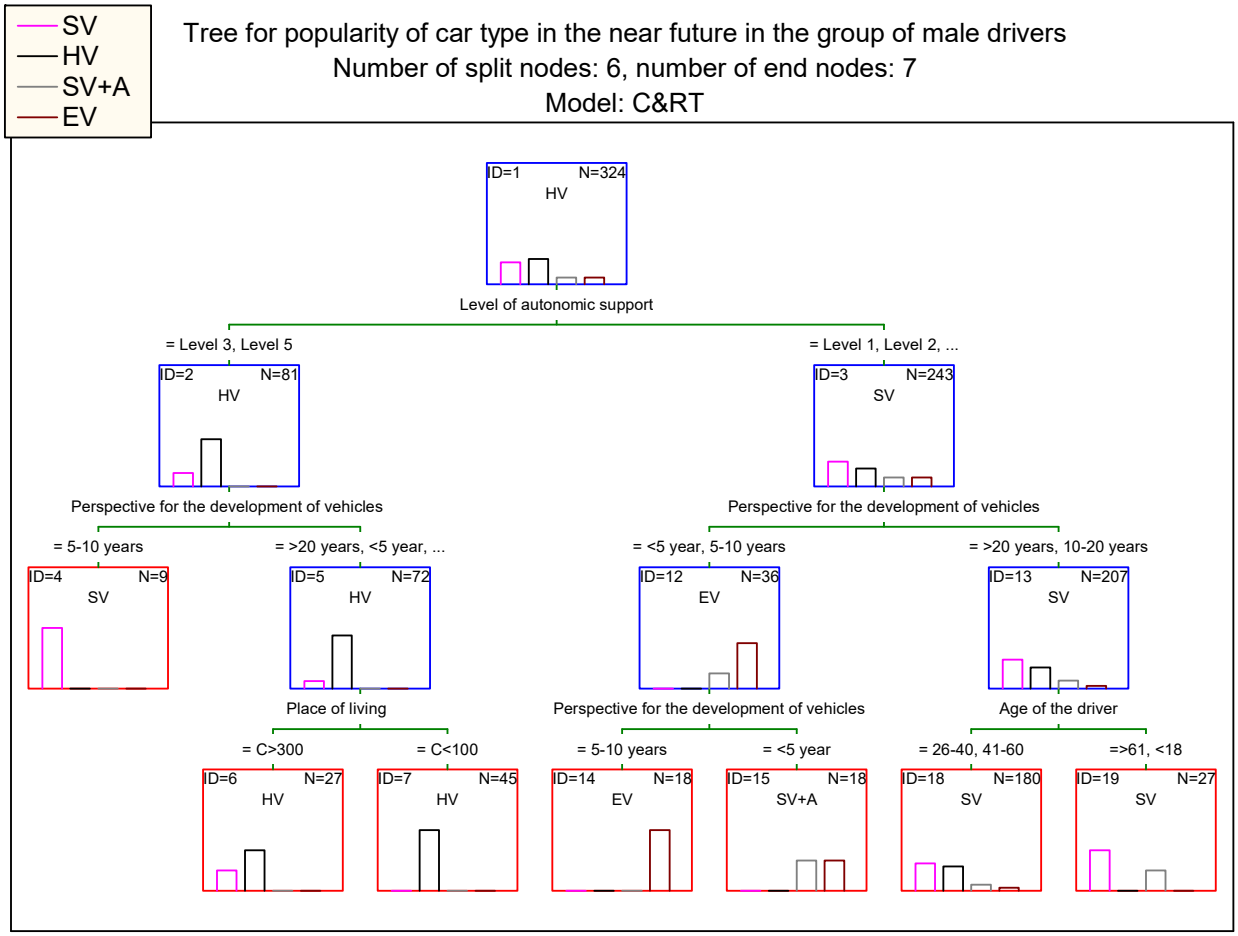


Figure 7. C&RT for the relationship between the popularity of individual types of systems used in passenger cars in the opinion of men, depending on such dependent variables as the level of vehicle autonomy, age of the driver, place of residence and the time when these cars will be popular in the future.

In the first node (ID = 1), n = 324 cases (i.e., men drivers) were identified in the entire dataset. As in the case of the group of women, the bars for the SV and HV categories are practically of equal size, which means that in our set, cases for which the values of the dependent variable meant traditional vehicles and hybrid vehicles prevailed.

In the next step, cases were separated, i.e., the rules were created that would predict them well. The variable that takes part in the division is the type of autonomy level in the declared types of vehicles. The men who chose Levels 3 and 5 definitely linked this fact to HVs. Men who chose Levels 1 and 2 think that the popularity of cars will be related to SVs.

With respect to other classification divisions, node ID = 4 means a separate group of drivers who see the popularity of cars with a standard system (gasoline or diesel engine) over the course of 5–10 years. Others thought that the popularity of HVs would be the greatest. This is a group that has been divided into the perspective of up to 5 years and over 20 years, but there are also people who live in small (up to 100,000 inhabitants) and large cities (over 300,000 inhabitants).

On the other hand, among the people who chose the autonomy Levels 1 and 2, two groups of drivers were distinguished, who see the perspective of vehicle market development primarily for electric cars (within 5–10 years) and for standard cars with autonomous support (within 5 years).

The last group for which the rule has been distinguished includes the age of drivers. Cars with a traditional system (SV) and hybrid system (HV) are indicated by respondents aged 26–40 and 41–60, while standard vehicles (SVs) and vehicles with autonomous support (SVs + A) are indicated by drivers aged up to 18 and over 61.

In line with the information listed in Table 3, as for men, seven rules have been created, according to which the probability of indicating a specific type of propulsion system is the highest for men living in large cities who have chosen the development of hybrid vehicles in the perspective of less than 5 years and over 20 years (probability was 66.7%)—ID = 6, and HVs for people living in small towns (ID = 7).

Table 3. Results in terminal nodes for the dependent variable: popularity of car type in the near future in the group of men. Model: C&RT.

	Class SV	Class HV	Class SV + A	Class EV	Gain	=v1/v5	=v2/v5	=v3/v5	=v4/v5
4	9	0	0	0	9.0000	100.0%	0.0%	0.0%	0.0%
6	9	18	0	0	27.0000	33.3%	66.7%	0.0%	0.0%
7	0	45	0	0	45.0000	0.0%	100.0%	0.0%	0.0%
14	0	0	0	18	18.0000	0.0%	0.0%	0.0%	100.0%
15	0	0	9	9	18.0000	0.0%	0.0%	50.0%	50.0%
18	81	72	18	9	180.0000	45.0%	40.0%	10.0%	5.0%
19	18	0	9	0	27.0000	66.7%	0.0%	33.3%	0.0%

As for men who chose lower levels of autonomy (Levels 1 and 2) and were aged 26–40 and 41–60, the probability that they indicated SVs and HVs was 45% (ID = 18). On the other hand, men under 18 and over 61 indicated traditional solutions (SVs)—ID = 19. Here, the probability of this choice was 66.7%.

The way people respond to innovative technologies depends on how much motivated they are by a wide array of internal and external factors as well as cost barriers they encounter [91]. Nevertheless, Li et al. [90] distinguished three main types of factors influencing the introduction of BEV technology, namely demographic, situational and psychological. A major barrier appears to be that consumers tend to resist new technologies that are deemed alien or unproved, thus, policy decisions that take into consideration their critical concerns will have a higher level of success [93]. To this end, it is possible to explain why electric vehicles are so popular in the Czech Republic as well. We have also ascertained, in analogy to the study [91], that people who switch vehicle preferences from conventional gasoline to plug-in vehicles are motivated by material factors and concerns about innovative technology. On the contrary, this shifting from less to more innovative technologies is likely motivated by a mix of tangible and intangible factors [117].

5. Conclusions

The article presents a survey whose main purpose was to ascertain the preferences of drivers (current or potential) in the Czech Republic regarding the propulsion system used in the vehicle. The following vehicles were taken into consideration: standard vehicle (SV), hybrid vehicle (HV), electric vehicle (EV), autonomous vehicle (AV) and standard vehicle supported by autonomous solutions (SV + A). Two grouping variables were used to analyze the results obtained, i.e., gender and place of residence of the respondents.

The research shows that women predict that in the near future the dynamic development of vehicles will mainly concern those with a hybrid system (HVs) and the development

of SVs, especially those supported by autonomous solutions (SVs + A). Similarly, men believe that the development will mainly concern HVs as well as traditional vehicles. Based on the conducted research and elaborated literature review, it can be concluded that when it comes to respondents from the Czech Republic and the USA, there is agreement as to the popularity of hybrid systems, followed by plug-in systems. In turn, barriers for EVs have been defined in a similar way.

In regard to the second grouping variable, i.e., place of residence, the results are as follows. People living in rural areas see the future only in SVs, followed by HVs. A similar approach can be noticed among respondents living in medium-sized cities (from 100,000 to 300,000 inhabitants), except that they equally see the popularity of not only SVs and HVs in the coming years but are also more inclined towards EVs. Residents living in small cities (up to 100,000 inhabitants) see the greatest prospects in the near future in hybrid vehicles. These people also see better prospects for SVs supported by autonomous functions rather than for EVs.

On the other hand, respondents living in large cities (over 300,000 inhabitants) see the best prospects for SVs, on a par with EVs. They further believe that HVs and SVs + A will enjoy slightly less interest in the future.

As apparent from the analysis, opinions differ and result from various reasons, so there is a need to continue research in this subject in the future.

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