Factors influencing public acceptance of self-driving vehicles in a post-socialist environment: Statistical modelling in Hungary

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The majority of social science studies on self-driving vehicles has focused on accepting technology using a methodology that investigates direct relationships only. However, there is an increasing demand for an in-depth social analysis of self-driving vehicle acceptance, exploring more complex relationships. Here, this challenge is responded to by the statistical modelling of the acceptance of self-driving technology, allowing for an exploration of the direct and indirect relationships among the relevant variables. Most previous studies have also been conducted in developed countries, and limited information is available on the acceptance of self-driving technology in less-developed countries.

The present study constructs an explanatory statistical model of the Hungarian population's concept of self-driving vehicles based on a representative sample of 1,001 participants. Furthermore, a graphical representation of the model is provided. The main results include the determination of the most influential factors on the acceptance of self-driving vehicles and the attribution of direct and indirect relationships among the variables, thus providing deeper knowledge than that previously obtained and complementing the currently available research results. Based on results, the expected advantages of self-driving technology have the greatest direct and total impact on the acceptance of this technology in Hungary. The enthusiasm for new technologies and the expected disadvantages of self-driving technology has a slightly weaker direct and second-largest total impact. Information needs on self-driving

technology, awareness of driving support systems, and perceived usefulness of new technologies had a weak but significant direct impact.
The results of study will provide essential information for the successful integration of self-driving technologies into the innovation systems of less-developed countries.

Keywords:
self-driving vehicles,
technology acceptance,
post-socialist,
PLS-SEM

Introduction

Although most studies on self-driving vehicles are in the technological or natural science domain, social science research on this topic has recently become more important. Particularly, while rapid progress is being made toward the deployment of self-driving vehicles, the readiness of the receiving environment will largely determine the success of this transition.

Self-driving vehicles will bring about tremendous changes in the everyday lives and routines of all participants in road traffic, such as drivers, cyclists, and pedestrians. However, it is not evident how they will be successfully integrated into the present situation (Cohen et al. 2020). Having the ability to be organised into a system: self-driving vehicles open radically new perspectives on mobility that will affect almost every area of our lives, creating new routines, travel habits, business models, networks, and urban structures (Palatinus et al. 2021).

Although, in some cases, tests are already taking place on public roads, self-driving vehicles are still considered experimental technologies. As such, they provide an excellent opportunity for extensive social science research. However, such research currently covers only a narrow portion of the topic (Cohen et al. 2018). Particularly, social science research on self-driving vehicles has mainly focused on the acceptance and use of self-driving vehicles. Contrastingly, Cohen et al. (2020) draw attention to the importance of in-depth social analysis. They suggest that it is necessary to explore and define more complex connections, direct and indirect relationships, and cultural and territorial specificities.

Accordingly, an increasing number of studies worldwide are focusing on statistical modelling to determine the acceptance of self-driving technology. Thus, we are becoming increasingly aware of the factors that influence attitudes toward self-driving vehicles worldwide (Benleulmi–Blecker [2017], Xing et al. [2020], Du et al. [2021]). Simultaneously, most of these studies have been conducted in developed countries. As the innovation environments of countries with different levels of development have an impact on technology acceptance (Straub et al. 1997, Phan et al. 2010, Ashraf et al. 2014, Jing et al. 2020), it is also important to obtain a clear understanding of how society's vision of self-driving vehicles can be modelled in less-developed countries.

The lack of surveys and statistical modelling regarding this topic in former socialist countries is particularly notable, and these countries are unique in terms of innovation. Many researchers implicitly assume that post-socialist countries suffer from shortcomings in their innovation cultures (e.g., low technological capability within companies, absence of industrial R&D, low business demand for innovation, and inappropriate science-push innovation policies) based on socio-cultural values and norms inherited from the socialist period, which appear to create immunity to innovation and resistance to adjustment (Kornai 2010, Teller–Validova 2015, Švarc 2017, Lukovics et al. 2017, Švarc–Dabić 2019).

These factors also affect technology acceptance, as has been verified using simple data analysis methods for self-driving technology (Tóth 2021). Thus, we consider it particularly important to examine which factors in post-socialist innovation environments most strongly determine the acceptance of self-driving technology.

This study explores the acceptance of self-driving technology among the Hungarian population in Hungary via statistical modelling (partial least squares structural equation modelling – PLS-SEM) and based on a comparison with international results, including different generations of the technology acceptance model (TAM) and the unified theory of the acceptance and use of technology (UTAUT). We develop and examine our model using a representative sample of 1,001 participants, and we study the indirect and direct relationships between the target variable and each factor. Furthermore, we highlight that, among the various factors, there are also variables (e.g., relations to other technologies) that, although are rarely found in other PLS models, are highly applicable in determining the acceptance of self-driving technology, according to international experience.

Key international studies on the acceptance of self-driving vehicles

The methodologies and results of technology acceptance surveys conducted on consumers in recent years were important starting points for determining the nature of the statistical model developed in this study. Several models have been widely used to identify consumer acceptance of technology, with the most commonly applied being the TAM (Davis 1986), the theory of planned behaviour (Ajzen 1985), the diffusion of innovation theory (Rogers, 2003), the UTAUT (Venkatesh et al. 2003), and the theory of reasoned action (Fishbein–Ajzen 1975).

In their applications of the TAM model, Moták et al. (2017) and Madigan et al. (2017) concluded that the perceived ease of use does not play a significant role in predicting consumer behaviour. However, Solbraa Bay (2016) concluded that the perceived ease of use strongly influences the intention to use, as was also found by Müller (2019) in the case of North America (but not Europe or China). Choi–Ji

(2015), Koul–Eydgahi (2018), Müller (2019), and Baccarella et al. (2020) conclude that perceived usefulness is the most important predictor of the acceptance and use of autonomous technology. According to the results of Zhang et al. (2020) and Liljamo et al. (2018), trust is another key factor in social acceptance, and it may be positively influenced by increasing the perceived safety of autonomous vehicles and raising awareness of their benefits.

Acheampong–Cugurullo (2019) and Panagiotopoulos–Dimitrakopoulos (2018) also demonstrated that subjective norms affect perceived usefulness, perceived ease of use, and perceived safety. According to Nordhoff et al. (2020), the strongest UTAUT2 variable regarding individuals' behavioural intentions was hedonic motivation. Nonetheless, the measurement method for hedonic motivation was a traditional online survey. Schoettle–Sivak (2014), Kyriakidis et al. (2015), and Hutchins–Hook (2017) found that most respondents tend to be concerned about autonomous vehicles and doubt their safety, while issues regarding legal and statutory liability were also raised. König–Neumayr (2017), Liljamo et al. (2018), Audi-Ipsos (2019), and Wang et al. (2020) identified the main rejection groups as women, elderly, people living in rural areas, and those with a lower level of education.

Choi–Ji (2015) used a PLS model to explore the role of trust in accepting self-driving vehicles with a sample of 635 participants. Benleulmi–Blecker (2017) developed a model for accepting self-driving vehicles. The UTAUT2 model conducted an online questionnaire survey of 160- and 153-participant samples in Germany and the United States, respectively. Based on their PLS-SEM model (in which only direct relationships were indicated), it was found that the acceptance of self-driving vehicles was influenced by both vehicle-related factors and factors related to the respondents' characteristics. Garidis et al. (2020) developed another model for user acceptance of autonomous driving. Building on the UTAUT model, an online questionnaire survey was conducted using a sample of 470 participants in Germany, after which a PLS-SEM model was developed, in which only direct relationships were analysed. The two most important positive influencing factors were safety and enjoyment, while the most important negative factor was the loss of control.

Wu et al. (2019) developed and tested an SEM model using a sample of 470 Chinese respondents focusing on environmental aspects, whereas Xing et al. (2020) researched the role of attitude toward technology in accepting self-driving minibuses. Their conceptual model combined the TAM with several widely accepted definitions of attitude. An online questionnaire survey was conducted at the University of California, West Village in the United States, using a sample of 176 participants. An SEM model in which both direct and indirect relationships were defined was developed, and trust was identified as the most important factor. Yuen et al. (2020) also investigated the acceptance of shared autonomous vehicles using a model based on a combination of UTAUT2 and theory of planned behavior (TPB). An SEM model that examined only direct relationships was developed based on an online questionnaire survey of a 268-participant sample in Da Nang, Vietnam. The authors found that perceived behavioural control had the greatest effect on the acceptance of self-driving vehicles.

Liu et al. (2019) researched people's willingness to pay for self-driving vehicles, focusing on demographic and psychological factors. In China, data was collected via a questionnaire with the assistance of interviewers in the two cities. Five hundred and eighty-six valid responses were received in Tianjin and 769 in Xi'an. Although the PLS model was not represented graphically, it was shown that younger, higher-educated, higher-income individuals would be more willing to pay higher prices for self-driving vehicles.

In China, Zhang et al. (2019) and Zhang et al. (2020) used an SEM on samples with 216 and 647 participants, respectively, to determine how trust and perceived risk affect the social acceptance of self-driving technology.

Du et al. (2021) analysed why travellers trust and accept self-driving vehicles, using social cognitive theory as a starting point upon which the acceptance model is based. In the process of data collection, 173 IT students completed paper-based questionnaires as part of a university class, and the results were used for PLS-SEM. In this model, both direct and indirect relationships were represented. Most significantly, they found that mass media greatly influenced early-stage technology acceptance.

Overall, it can be seen that several recent studies have examined the social acceptance of self-driving vehicles worldwide. Most of these have proceeded from some versions of the TAM or UTAUT, and several methodological approaches have been applied. Further, it is striking that most research has focused on social acceptance in developed countries.

Available information on social acceptance of self-driving vehicles in post-socialist contexts

Over the past few years, there has been an increasing focus on research in the social acceptance of self-driving vehicles in post-socialist countries. In fact, of the post-socialist countries, only the Czech Republic and Hungary can be found in KPMG's 2020 AV readiness index. The Czech Republic is ranked 23rd among 30 countries, while Hungary is ranked 25th (KPMG 2020).

Gabrhel et al. (2019) surveyed public opinion on autonomous vehicles in the Czech Republic using a representative sample of 1,065 people and performed bivariate data analysis methods on the obtained data. Policy proposals were then formulated based on the results, which focused primarily on the preparation of the receiving environment. Havlíčková et al. (2019) surveyed 1,116 Czech residents using a questionnaire, based on which they researched the role of gender and age concerning general attitudes and media preferences. In terms of research methodology, this investigation relied on descriptive statistics and bivariate data analysis methods, and the researchers were able to identify the main rejection groups in Czech society.

In Hungary, an increasing number of social science studies are being undertaken on issues related to self-driving vehicles, but the vast majority of these studies are theoretical in nature. In particular, from a theoretical point of view, Hungarian researchers have addressed moral (Miskolczi et al. 2021) and legal issues (Ambrus 2019, Kecskés 2020), the relations to responsible innovation (Lukovics et al. 2020) and cities (Lados–Tóth 2019, Smahó 2021), the impact on government budget and employment (Gyimesi 2019) as well as on lifestyle and economy (Banyár 2019), social effects, and acceptance (Csizmadia 2019, Páthy 2019, Szemerédi 2019).

Madarász–Szikora (2018) conducted an empirical study on the social acceptance of self-driving vehicles. Using an online questionnaire, they formulated their conclusions using a descriptive statistical methodology based on a non-representative sample of 207 participants. In addition, Majó-Petri–Huszár's (2020) primary survey examined attitudes and intentions regarding the use of self-driving vehicles using a questionnaire-based method. The researchers worked with a non-representative sample of 314 participants, analysed using descriptive statistics. Thereafter, PLS modelling was performed per the factors validated in the car technology acceptance model (CTAM). It was found that three of the examined factors, namely, attitude, safety, and social impact, had a significant impact on the participants' intention to use self-driving vehicles. Indirect relationships were not examined in the model. It is important to note that a critical mass of interest in self-driving technology has not yet been detected in Hungary, so neither high consumer expectations nor significant acceptance or rejection can be observed.

Csizmadia (2021) examined the Hungarian population's awareness, experiences, and general opinions regarding autonomous and self-driving vehicles using a representative sample of 1,001 participants.[1] In terms of methodology, descriptive statistics, an analysis of variance, and cross-tabulation analysis were applied. Overall, the study found that news and awareness of autonomous/self-driving vehicles are becoming more widespread (with 60–70% of the population aware of the technology). However, only a very narrow segment of the population (4%–5%) has had direct experiences or experiences of using vehicles equipped with self-driving solutions and automated functions.

Using descriptive statistics as a methodology, Páthy (2021) examined attitudes toward self-driving technology through a representative sample of 1,001 participants based on the degree of agreement with several concretely definable advantages and

[1] The sample used in the research is the same as the present research. The database is described in section Modelling.

disadvantages regarding autonomous vehicles. In addition to individual analyses of the variables belonging to each group of factors with the examined statements, multivariate models (binomial logistic regression) were also developed to compare the strengths of the effects. Examining the results on statements highlighting the positive and beneficial features of autonomous vehicles throughout the sample, it is striking that the overall proportion of those who mostly or completely agreed did not exceed 50% for any single statement. Thus, it can be stated that in all cases, the majority were sceptical of, or to some extent, rejected the potential benefits of self-driving cars.

Manfreda et al. (2019) conducted an analysis in Slovenia in a post-socialist innovation environment, and the acceptance factors for self-driving vehicles were investigated using SEM. Data was collected from a sample of 382 participants using an online questionnaire. It was concluded that the perceived benefits of self-driving vehicles were vital factors in acceptance, while their perceived safety significantly impacted the influence of various concerns. However, this research was limited to 20–30-year-olds.

As outlined above, PLS-SEM, which can help determine connections in-depth and explore direct and indirect relations, has been performed in a meagre number of post-socialist environments. Further, no model has been developed to examine the factors regarding the social acceptance of self-driving vehicles for the entire population of a post-socialist country by exploring direct and indirect connections. To eliminate this scientific gap, PLS-SEM is performed for the Hungarian society.

Modelling

Our empirical study examines the direct and indirect influences on self-driving technology acceptance using PLS-SEM, which includes simultaneously performed regression and factor analyses. Particularly, the method involves a family of special equations of SEM, in which path analysis is performed based on the PLS method. The procedure aims to explain the variance in latent target variables fully. One key advantage of using PLS-SEM instead of other structural models is that there is no precondition regarding the normality of the variables included in the analysis, and a manifest (directly observable variable) may underlie a latent variable. The use of this modelling technique is usually recommended in exploratory studies (Kazár 2014). In addition to the causal relationships among latent variables, the correlations and direct and indirect effects can also be examined.

Database

In our study, we used data from a questionnaire survey conducted at the request of Széchenyi István University by the Závecz Research Market and Social Research

Institute in 2019 on 1,001 participants[2]. The multistage stratified sample represents the Hungarian population over 18 years based on gender, age, and legal settlement status. Overall, 55.1% of the respondents were women, and 44.9% were men. Additionally, 29.4% of the respondents lived in villages, 35.4% in smaller rural towns, 17.1% in cities with county rights, and 18.1% in the capital. The average age of the respondents was 49 years (Csizmadia 2021).

Initial model

The PLS model consists of an internal and an external model. The internal model describes the causal link between latent variables (constructions), whereas the external model describes the relationships between latent and manifest variables (in our case, the questionnaire questions). In the internal model, the acceptance of self-driving technology was included as a target variable, to which four manifest variables were related to the external model:

- *In total, how many types of transport modes can you imagine using full self-driving solutions and technologies in the future?*

  The questionnaire included eight different forms of transport [personal car, rented/company car, shared car, bus, short-distance fixed-track transport (suburban railway line, metro, tram, etc.), train, water transport (boat, ferry, etc.), and plane] with separate questions asking whether the respondents could imagine full self-driving solutions and technologies in the future for each form. The variable used in the analysis was constructed as the sum of these variables. Therefore, its value was between 0 and 8. Seventy-five per cent of respondents could imagine self-driving vehicles in the future, while the respondents mentioned an average of 2.4 forms of transport. Of the 750 people who envisioned at least one form of full self-driving transport, the most (54%) envisioned it in the case of fixed-track transport (suburban railway line, metro, tram, etc.), and the least (26%) in the case of water and air transport. In the case of personal vehicles, full self-driving technology was considered conceivable by 45% of respondents.
- *Could you replace your conventional vehicle with a full self-driving vehicle?*

  For this question, 61% of the 1,001 respondents said they would use only a conventional car, 32% said they would use a mix of conventional and self-driving technology, and 7% said they would use self-driving technology alone.

[2] The following definition was read out to the respondents at the beginning of the survey: '*The concept of a self-driving vehicle is understood as the highest level of automation. In this case, all the tasks related to driving are taken over by the vehicle, not requiring human operation to navigate, which is based on the communication of the external environment sensors and the management software.*'

- *How interested would you be in buying and using a fully self-driving vehicle? (five-degree scale)*

  Approximately 69% of respondents indicated that they would not be interested in buying a fully self-driving vehicle, while 11% said they would be interested.
- *What is your general opinion on self-driving technology based on the information currently available? (five-degree scale)*

  On a self-assessment basis, 27% of respondents had a more negative opinion on self-driving technology, 23% had a more positive opinion, and 53% had a neutral opinion.

We based our development of explanatory latent variables using the models reviewed in the literature. As common experience indicates that few have direct experience with self-driving technology, its features are challenging to assess. Therefore, we included only certain components of the TAM, CTAM, and UTAUT in our model as explanatory variables. The latent explanatory variables are described below.

Expected advantages and disadvantages of self-driving technology

In each examined model, the expected advantages and disadvantages include technological, environmental, legal, safety, operational, and social advantages and disadvantages. In some models, these are considered single integrated factors and in others as separate factors.

The questionnaire used a four-point scale to map the degree to which respondents agreed with the expected advantages/benefits of self-driving cars based on the following 12 statements:

- *They will be safer than conventional vehicles.*
- *They will provide the opportunity to do activities other than driving during free time.*
- *They will reduce travel time.*
- *They will consume less fuel than conventional vehicles.*
- *They will be less damaging to the environment than conventional vehicles.*
- *They will provide the opportunity to use the vehicle independently,* even for those who have difficulty with driving or face other obstacles.
- *Optimal use will result in longer life and slower depreciation.*
- *Repair and service costs will be reduced.*
- *Insurance costs will be reduced.*
- *Longer journeys can be made more easily and conveniently.*
- *Parking difficulties and costs will be reduced.*
- *Money and time on learning to drive can be saved.*

Overall, 71% of the respondents expected self-driving vehicles to have some advantages. The greatest number of such respondents were influenced by more comfortable longer journeys (69%), the opportunity to drive for those with challenges (69%), the opportunity to do other activities in their free time (63%), and reduced environmental damage (63%). Respondents saw the least benefit in reducing service and insurance costs, which were expected by only 39% and 42% of respondents, respectively.

Similarly, the expected disadvantages and risks were examined using the following ten statements:

- *Self-driving vehicles may not be safe in all environments or under certain conditions (e.g., bad weather).*
- *Self-driving vehicles will be at the risk of obtaining or modifying driving input data from outside.*
- *Self-driving vehicles will allow children to use the car alone without supervision.*
- *Self-driving vehicles will be able to drive without a passenger.*
- *In general, I would not feel safe in a self-driving vehicle.*
- *The presence of self-driving vehicles would reduce my sense of security because I lack enough knowledge of self-driving technology.*
- *I do not have trust in computers and artificial intelligence.*
- *I like driving, and I like to control the vehicle completely. I do not want to transfer that control.*
- *With the spread of self-driving vehicles, traffic will increase.*
- *Self-driving technology will be very expensive, and the costs of purchasing a vehicle and vehicle maintenance will increase significantly.*

Overall, 89% of the respondents were afraid of some risks or disadvantages of self-driving vehicles. Additionally, at least 60% of the respondents mentioned each listed disadvantage and risk. Respondents saw the greatest risk in the external obtainment of driving data (77%), an increase in purchase and maintenance costs (75%), and a lack of safety in all environments (75%).

To determine the number of factors necessary to incorporate into our model to reflect these various advantages and disadvantages, we performed a principal factor analysis using the SPSS program. Based on the Kaiser–Meyer–Olkin (KMO) indicator, it made sense in both cases to search for background variables underlying each variable. In the case of both advantages (KMO=0.943) and disadvantages and risks (KMO=0.918), the procedure suggested using a single factor. Therefore, our model describes the advantages and disadvantages of using each factor, assuming that each directly affects the acceptance of self-driving technology.

Orientation to technology

In the model proposed by Manfreda et al. (2019), it was found that the acceptance of self-driving technology was related to respondents' general orientation toward technology. To describe this based on more complex indicators: three latent variables (enthusiasm for new technologies, perceived usefulness of new technologies, and current domestic technology) were used instead of a single latent variable, and these variables were also used as explanatory factors in our model. The existence of these three latent variables was further confirmed by principal factor analysis (KMO=0.869).

Enthusiasm for new technologies was examined through seven statements focusing on different areas of everyday life using a ten-point scale, where a higher value means fewer concerns and more enthusiasm:

- *In the future, industrial production in factories will largely be done by computers and robots.*
- *In the future, there will be no need for administrators to manage our day-to-day issues; everything will be automated or solved virtually from home (identity card preparation, government/customer services, etc.).*
- *In the future, there will be healthcare interventions and services that can be used in an automated and mechanized way, requiring human participation only in the field of supervision (patient transport, patient management systems, clinical identification photos, etc.).*
- *In the future, personalized education and training that are independent of the location of the educational institution will be realized in a virtual educational space with independent participation at any time of the day, and there will be no need for personal meetings with instructors.*
- *Within the foreseeable future, vehicles, public transport, and private transport will be operated without the need for human drivers because the vehicles will be autonomous and self-driving.*
- *We can spend our free time in virtually created worlds, where all forms of recreation can be tested and experienced.*
- *It will be possible to establish emotional and physical contact with virtual people animated by artificial intelligence.*

The average level of enthusiasm, except with regard to establishing emotional and physical contact with virtual persons, was between 4 and 5 for each statement. However, the relative standard deviation for each statement was greater than 50%. Therefore, we describe these questions based the medians (Me). People were found to be the least enthusiastic about establishing emotional and physical contact with virtual persons (Me=3), spending virtual leisure time (Me=4), and automated healthcare services (Me=4). For all other statements, the median value was 5 (i.e., the respondents were divided in terms of enthusiasm).

Our model assumes that the enthusiasm for new technologies directly impacts the perceived usefulness of new technologies, the expected advantages and disadvantages of self-driving technologies, and the awareness of driving support systems.

The perceived usefulness of new technologies was analysed for the following three statements using a five-point scale:

- *We are saving time with new technologies.*
- *New technologies make our lives more simple.*
- *New technologies provide solutions to many problems.*

For each question, the average answer was 3.5, and the median was 4. The majority of respondents were focused on the advantages of the new technologies rather than their disadvantages. Our model assumes that the perceived usefulness of new technologies directly impacts the expected advantages of self-driving technologies and the use of domestic technology.

The third factor regarding technology orientation is domestic technology use, which was described by two questions:

- *How many kinds of smart devices are there in your household?*

  This question included 11 household devices (thermostat, measuring units, and their control units, online remote controls, smart lighting, smart locks, CCTV and closed-circuit camera systems, alarm systems, smart coolers, robotic vacuum cleaners, robotic lawnmowers, automated garden irrigation systems, remote-controlled windows, and mobile connections between different home devices), from which we formed the variable used in the model. Therefore, the variable had a value between 0 and 11. Sixty-nine per cent of respondents had none of the indicated devices in their household, 20% had one device, and only 1% had at least five of the given devices. The most common smart devices were mobile connections between different home devices (173 people), alarm systems (123 people), thermostats, measuring units and their control units, and online remote controls (83 people).
- *How many kinds of smart devices do you use in your household?*

  This question included 16 home smart devices [home cinema systems; video and/or audio streaming services (Chromecast, Hulu, Netflix, HBO Go, etc.), smart TVs, smart speakers or personal assistants, smartphones or tablets, laptop or desktop computers, gaming machines or consoles (XBOX, PlayStation, etc.), VR goggles, e-readers, 3D printers, action cameras or drones, scanners, printers or photocopiers, digital cameras or camcorders, smartwatches, smart systems, from which we formed the variable used in the model (based on daily use). Therefore, the variable had a value between 0 and 16 – approximately 79% of the respondents used at least one of the tools listed daily. The most frequently used devices were smartphones or tablets (680 people), laptops or desktop computers (669 people), digital cameras or camcorders (291 people), and smart TVs (279 people). The least common were sleep monitoring systems, sports trackers, drones, 3D printers, VR goggles, smart speakers, and e-readers (less than 5% of respondents each).

In our model, we assume that domestic technology use has a direct effect on the acceptance of self-driving technology.

Awareness of driving support systems

This study assumes that awareness of driving support solutions positively affects the acceptance of self-driving technologies and the expected advantages. The awareness of driving support solutions was examined through knowledge of seven functions (automatic speed control depending on the speed limit for that section of the road, ability to stay in the right lane without steering, automatic tracking of the distance from the vehicle in front, ability to change lanes without driver intervention, ability to avoid collisions with other vehicles or objects, autonomous navigation to a selected destination, and autonomous parking). Therefore, this fabricated dimension was characterised by a single variable calculated based on seven questions. Therefore, it had a value between 0 and 7. Respondents were familiar with an average of four of the seven given tools, and 78% were familiar with at least one of the listed driving support solutions. Respondents were most familiar with automatic parking systems (656 people) and speed control as a function of speed limit (633 people).

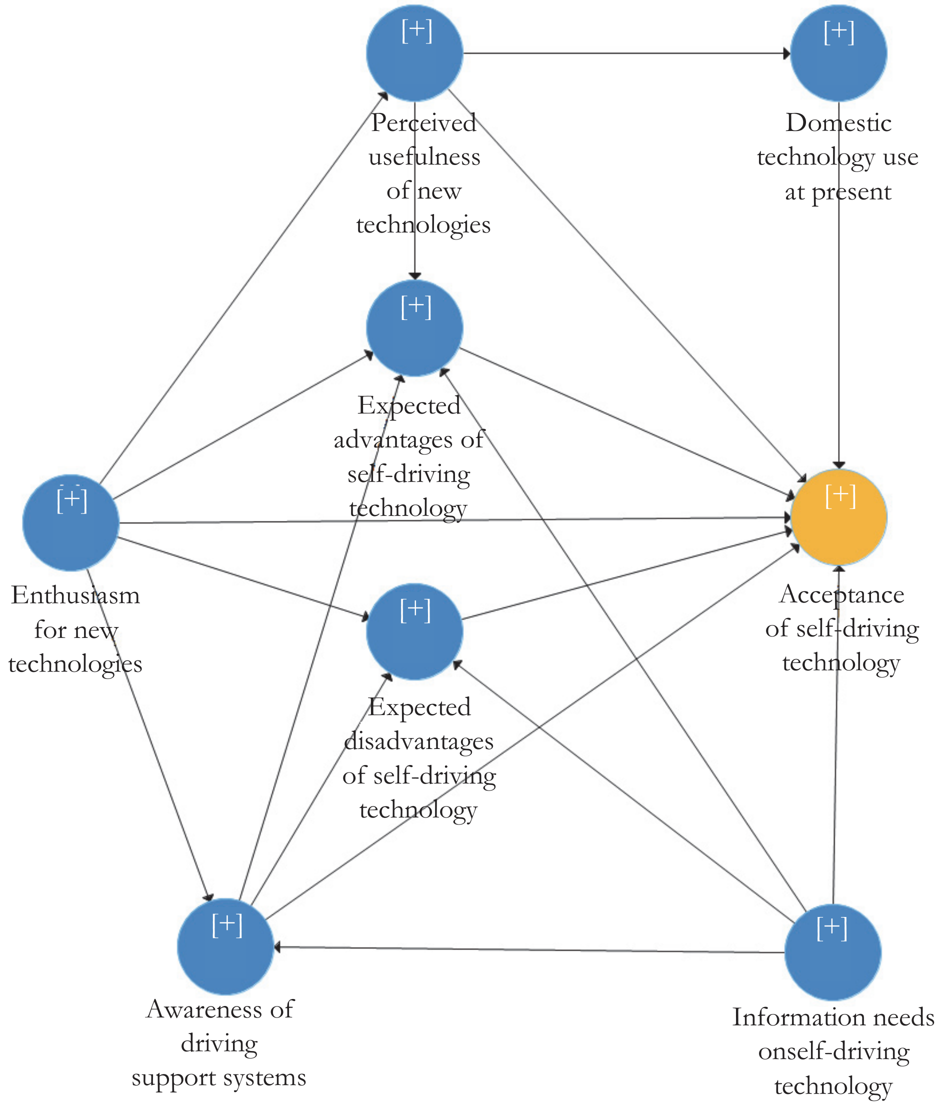
Information needs on self-driving technology

We assumed that the awareness of driving support solutions, the acceptance of self-driving technology, and the expected advantages and disadvantages of self-driving technology depend on how well informed the respondents are and the degree to which they are motivated to collect information on self-driving technology. To measure awareness, we formed a variable based on a question. It examines how many out of eight information sources were used by respondents to inform themselves about self-driving vehicles (newspaper, TV, radio, the Internet, social networking sites, family members, acquaintances, and personal experience). It was found that 59% of respondents used at least one source of information to gather information about self-driving technology. Further, the users of information sources used an average of 2.51 sources, with the most common being TV (80%) and the Internet (63%). The proportion of users of other sources was less than 30%, with personal experience being the lowest (8%).

Eight latent variables were included in the model (Figure 1).

Figure 1

Initial internal model in Hungary, 2019



Results

In this section, the acceptance of self-driving technology with the help of the PLS-SEM model is analysed. First, we focus on the goodness of the latent variables. Second, the latent variables' direct, indirect, and total effects on other latent variables and the correlation between the latent variables is analysed using SmartPLS3 software.

Verification of latent variables

There is no global indicator describing the goodness of fit of the entire PLS-SEM model. When examining the model's features, we analysed the goodness of the latent variables (reliability, discriminant validity, and convergent validity) and the significance of the direct effects (path coefficients; Henseler et al. 2009).

The reliability of latent variables can be examined using the composite reliability index, with the threshold value for reliability being 0.7 (Kovács–Bodnár 2017).

For convergent validity, we examined whether a set of variables was representative of a given latent variable. This can be characterised by the average variance extracted (AVE) indicator. The AVE value is expected to be at least 0.5 (Horváth 2016, Mitev et al. 2017), which in our case was satisfied (Table 1).

Table 1

Main features of the latent variables in Hungary, 2019

Latent variables	Composite reliability	AVE
Enthusiasm for new technologies	0.936	0.679
Domestic technology use at present	0.843	0.733
Awareness of driving support systems	1.000	1.000
Information needs on self-driving technology	1.000	1.000
Expected advantages of self-driving technology	0.948	0.603
Expected disadvantages of self-driving technology	0.916	0.529
Perceived usefulness of new technologies	0.959	0.887
Acceptance of self-driving technology	0.835	0.560

We examined whether the latent variables were sufficiently separated during the discriminant validity analysis. This can be performed using the Fornell–Larcker criterion and the heterotrait–monotrait (HTMT) correlation ratio (Table 2). For the former, we checked whether the square root of the latent variables' AVE (in the main diagonal) was higher than their pairwise correlation with the other latent variables. The average correlation with the associated manifest variable will then be higher than its correlation with other factors. The numerator of the HTMT correlation ratio gives the average of the pairwise correlation coefficients between the manifest variables associated with the two latent variables, and the denominator represents the average of the pairwise correlation coefficients between the manifest variables related to the same factors. To achieve discriminant validity, the values of the HTMT indices must be below 0.9 (Henseler et al. 2015, Kovács–Bodnár 2016).

Table 2

Analysis of discriminant validity in Hungary, 2019

Latent variables	Enthusiasm for new technologies	Domestic technology use at present	Awareness of driving support systems	Information needs on self-driving technology	Expected advantages of self-driving technology	Expected disadvantages of self-driving technology	Perceived usefulness of new technologies	Acceptance of self-driving technology
				Analysis of the Fornell–Larcker criterion				
Enthusiasm for new technologies	0.824							
Domestic technology use at present	0.130	0.856						
Awareness of driving support systems	0.231	0.316	1.000					
Information needs on self-driving technology	0.169	0.314	0.551	1.000				
Expected advantages of self-driving technology	0.397	0.195	0.344	0.280	0.777			
Expected disadvantages of self-driving technology	−0.289	−0.020	−0.096	−0.048	−0.175	0.727		
Perceived usefulness of new technologies	0.233	0.225	0.252	0.220	0.273	−0.087	0.942	
Acceptance of self-driving technology	0.507	0.245	0.389	0.350	0.666	−0.347	0.316	0,748
				HTMT correlation ratio values				
Enthusiasm for new technologies	0.146							
Awareness of driving support systems	0.236	0.331						
Information needs on self-driving technology	0.175	0.332	0.551					
Expected advantages of self-driving technology	0.422	0.219	0.352	0.284				
Expected disadvantages of self-driving technology	0.289	0.081	0.101	0.074	0.189			
Perceived usefulness of new technologies	0.246	0.233	0.260	0.226	0.284	0.101		
Acceptance of self-driving technology	0.611	0.304	0.439	0.396	0.787	0.375	0.370	

Analysis of direct, indirect and total effects

To analyse the significance of the direct effects, we used 5,000 subsamples for bootstrapping (Table 3). Based on the analysis, it was concluded that all the direct effects were significant, except for two. The two nonsignificant effects on the expected disadvantages were awareness of driving support systems and information needs regarding self-driving technology. This is in line with Páthy's conclusion that the expected disadvantages are not affected by a lack of information or solutions.

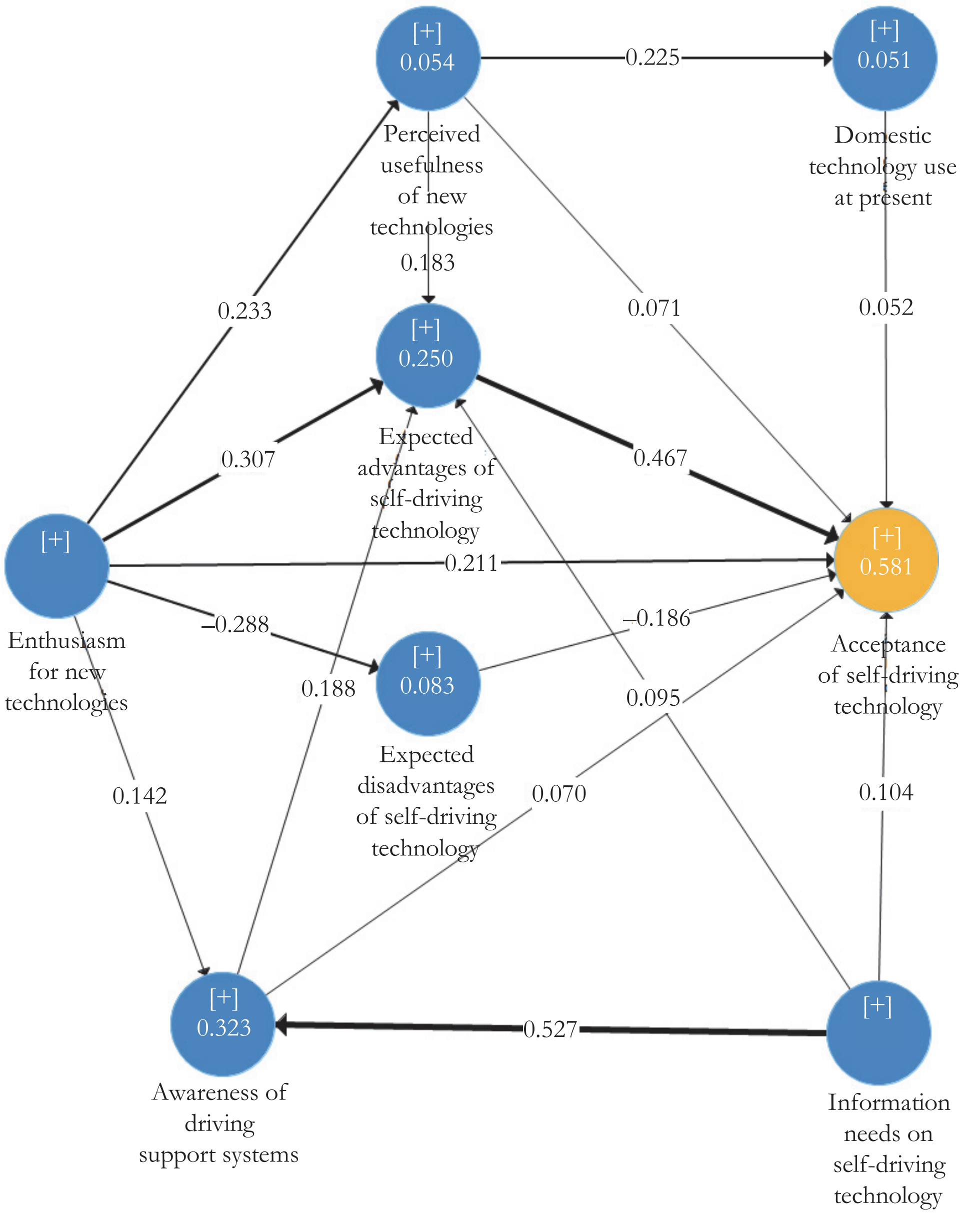
Table 3

Results of path coefficients analysis in Hungary, 2019

Relationship	Path coeffi-cient	t-value	p-value
Enthusiasm for new technologies -> Awareness of driving support systems	0.142	5.011	<0.001
Enthusiasm for new technologies -> Expected advantages of self-driving technology	0.307	9.807	<0.001
Enthusiasm for new technologies -> Expected disadvantages of self-driving technology	−0.283	8.52	<0.001
Enthusiasm for new technologies -> Perceived usefulness of new technologies	0.233	6.749	<0.001
Enthusiasm for new technologies -> Acceptance of self-driving technology	0.211	8.648	<0.001
Domestic technology use at present -> Acceptance of self-driving technology	0.052	2.457	0.014
Awareness of driving support systems -> Expected advantages of self-driving technology	0.188	5.43	<0.001
Awareness of driving support systems -> Expected disadvantages of self-driving technology	−0.044	1.145	**0.252**
Awareness of driving support systems -> Acceptance of self-driving technology	0.07	2.719	0.007
Information needs on self-driving technology -> Awareness of driving support systems	0.527	24.952	<0.001
Information needs on self-driving technology -> Expected advantages of self-driving technology	0.095	2.936	0.003
Information needs on self-driving technology -> Expected disadvantages of self-driving technology	0.024	0.714	**0.475**
Information needs on self-driving technology -> Acceptance of self-driving technology	0.104	3.903	<0.001
Expected advantages of self-driving technology -> Acceptance of self-driving technology	0.467	19.67	<0.001
Expected disadvantages of self-driving technology -> Acceptance of self-driving technology	−0.186	8.457	<0.001
Perceived usefulness of new technologies -> Domestic technology use at present	0.225	7.601	<0.001
Perceived usefulness of new technologies -> Expected advantages of self-driving technology	0.133	4.444	<0.001
Perceived usefulness of new technologies -> Acceptance of self-driving technology	0.071	3.136	0.002

Figure 2

Model of self-driving technology acceptance in Hungary, 2019



The final model was formed after eliminating nonsignificant paths (Figure 2). The explanatory forces are shown inside the latent variables, while the arrows show the path coefficients (standardised regression beta coefficients). Overall, this model describing the acceptance of self-driving technologies was found to have an explanatory power of 58.1%. The expected advantages of self-driving technology had the greatest direct impact on acceptance (beta=0.467). In other words, the stronger one considered the advantages of self-driving technology to be, the more accepting they were of this technology. A direct adverse effect (beta=−0.186) was observed in terms of expected disadvantages. In other words, the stronger one considered the disadvantages and risks of self-driving technology to be; the less accepting they were of this technology. Comparing the values of the standardised path coefficients revealed that the expected advantages had a 2.5 times stronger effect on the acceptance of self-driving technology than the expected disadvantages. Enthusiasm for new technologies had a direct positive effect on the acceptance of self-driving technology (beta=0.211). Additionally, this factor had a moderately positive effect on the expected advantages of self-driving technologies (beta=0.307) and the perceived usefulness of new technologies (beta=0.233), as well as a weak positive effect on the awareness of driving support systems (beta=0.142). Furthermore, it had a moderately adverse effect on the expected disadvantages of self-driving technologies, through which it indirectly affected the acceptance of self-driving technology. The magnitude of this effect (resulting from the product of the path coefficients of the connecting paths) was 0.253, which is almost equal to the magnitude of the direct effect. Consequently, similar to the expected advantages of self-driving technology, the overall effect of enthusiasm for new technologies on the acceptance of self-driving technology was strong and positive (0.253+0.211=0.464).

Information needs on self-driving technology were found to have a positive but weak direct effect (beta=0.104) on the acceptance of self-driving technology and the expected advantages of self-driving technology (beta=0.095). Simultaneously, it had a strong positive effect (beta=0.527) on awareness of driving support systems. Through this, it had a direct effect on the acceptance of self-driving technology, similar to the strength of the indirect effect (0.527×0.070+0.527×0.188×0.467=0.128), thus having the third strongest total effect (0.128+0.104=0.232) on the acceptance of self-driving technology.

Awareness of driving support systems, perceived usefulness of new technologies, and domestic technology use at present were all found to have a positive but weak effect on the acceptance of self-driving technology, whereas their indirect effects were at least as great as their direct effects.

Overall, it can be concluded that the expected advantages of self-driving technology and enthusiasm for new technologies have the greatest impact on the acceptance of self-driving technology. Information needs on self-driving technology, the expected disadvantages of self-driving technology, the awareness of driving support systems, and the perceived usefulness of new technologies had a slightly weaker impact (Table 4).

Table 4

Effects of latent variables on autonomous technology acceptance in Hungary, 2019

Latent variable	Direct effect	Indirect effect	Total effect
Expected advantages of self-driving technology	0.467		0.467
Enthusiasm for new technologies	0.211	0.253	0.464
Information needs on self-driving technology	0.104	0.127	0.232
Expected disadvantages of autonomous technology	−0.186		−0.186
Awareness of driving support systems	0.070	0.096	0.166
Perceived usefulness of new technologies	0.071	0.074	0.145
Domestic technology use at present	0.052		0.052

Examining the correlations among the factors: it can be seen that the acceptance of self-driving technology had a medium-strength positive correlation with enthusiasm for new technologies, awareness of driving support systems, and expected advantages of self-driving technology (Table 5).

Table 5

Correlations between latent variables in Hungary, 2019

	Domestic technology use at present	Awareness of driving support systems	Acceptance of self-driving technology	Information needs on self-driving technology	Expected advantages of self-driving technology	Expected disadvantages of self-driving technology
Enthusiasm for new technologies	0.130	0.231	**0.507**	0.169	0.397	−0.288
Domestic technology use at present	1	0.316	0.245	0.314	0.195	−0.020
Awareness of driving support systems		1	0.389	**0.551**	0.344	−0.096
Acceptance of self-driving technology			1	0.35	**0.666**	−0.347
Information needs on self-driving technology				1	0.28	−0.047
Expected advantages of self-driving technology					1	−0.174
Expected disadvantages of self-driving technology						1

Discussion

We aim to link our results to the relevant findings of international studies in related fields. However, it is important to highlight that a broader comparison is not possible due to the differences in the samples, the method of enquiry, the base technology acceptance model (TAM, UTAUT), or the differences in the analytical methodologies used. Responsibly and reasonably, we only have the opportunity to name the strongest relationships of the studies prepared with the PLS-SEM methodology, noting that the naming of the given variables is the result of the analyst's subjectivity; moreover, the questions and variables behind can differ significantly, thus being unsuitable for drawing deep and detailed conclusions but suitable for establishing a general context only.

The main results of the PLS-SEM studies are highlighted below, involving the results of the two post-socialist countries, Hungary and Slovenia. The literature suggests that people who are more open to new technologies will likely adopt new technologies (Manfreda et al. 2019, Garidis et al. 2020), which we confirmed for adopting autonomous vehicles (Table 6).

Table 6

Comparing the results of similar studies

Our study *Hungary*	Manfreda et al. (2019) *Slovenia*	Garidis et al. (2020) *Germany*	Benleulmi–Blecker (2017) *Germany, USA*	Yuen et al. (2020) *Vietnam*	Liu et al. (2019) *China*	Du et al. (2021) *China*
Expected advantages of self-driving technology	Technologically minded individuals	Safety	Performance Risk	Perceived behavioural control	Perceived dread	Adoption Intention
Enthusiasm for new technologies	Perceived personal and societal benefits of AV	Hedonic motivation	Hedonic Motivation	Hedonic motivation	Trust in SDVs	Trust
Information needs on self-driving technology	Perceived safety of AV	Desire for control	Social Influence	Performance expectation	Perceived risk	Self-efficacy
Expected disadvantages of autonomous technology	Perceived technological and legal concerns related to AV	Cost	Personal Innovativeness in IT	Price value	Perceived benefit	Subject Norms
Awareness of driving support systems	Perceived mobility-related efficiencies of AV	Social influence	Desirability of Control	Effort expectation	–	Mass media
Perceived usefulness of new technologies	Perceived security of AV	Security	Trust	Habit	–	–

The benefits of self-driving vehicles appear in various places in the international literature (Manfreda et al. 2019, Liu et al. 2019), which in our case, proved the strongest direct and complete relationship. It should be mentioned as an interesting factor that the key aspect of the benefits, hedonic motivation, was the second strongest factor in three studies (Garidis et al. 2020, Benleulmi–Blecker 2017, Yuen et al. 2020); however, this was not confirmed in either the Hungarian or the Slovenian data.

Interestingly, the factors representing disadvantage, uncertainty, and fear were significant only in the Hungarian, Slovenian, and Chinese samples, whereas such factors did not emerge in other studies.

Conclusions

This study examined how various factors directly or indirectly affect self-driving technology acceptance in Hungary using PLS-SEM. In this study, a model based on a representative sample of 1,001 respondents was developed, in which the direct and indirect relationships between the target variable and individual factors were examined, thus providing the opportunity to explore various correlations deeply. To the best of our knowledge, a study of this volume and using this methodology has not yet been conducted for Hungary or any other post-socialist country.

Based on our investigation of direct relationships, the results of our study indicate that the expected advantages of self-driving technology have the greatest impact on the acceptance of this technology in Hungary. The enthusiasm for new technologies and the expected disadvantages of self-driving technology was found to have a slightly weaker impact. Information needs on self-driving technology, awareness of driving support systems, and perceived usefulness of new technologies had a weak but significant direct impact.

In mapping the mechanism of the effects, our substantial finding is that it is insufficient to examine the direct effects only. Instead, the indirect effects (those mediated by other factors) were also crucial in determining which factors had the greatest influence on the acceptance of self-driving technology. Accordingly, the expected advantages of self-driving technology and enthusiasm for new technologies were found to have the greatest (and almost identical) effect on the acceptance of self-driving technology in Hungary. Information needs on self-driving technology and awareness of driving support systems had a slightly weaker effect. Meanwhile, the total effect was twice as large as the indirect effect for the latter two factors.

It should be noted that, among the various factors, there were also variables (e.g., relations to other technologies) that, according to international experience, are highly significant in determining the acceptance of self-driving technology but are rarely found in other PLS models.

The results of our research can provide essential information for the successful integration of self-driving technologies in the innovation systems of less-developed countries. The findings of this study may also serve as a crucial resource for transport operators and governments to enhance transportation services and policies.

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