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Examining the Expected Impacts of Autonomous Vehicles on Transport, Their Cross-Impacts and the Relationships Between Impacts †

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Abstract: We have a promising future in improving road safety, which requires a comprehensive assessment of the impact of systems on road transport. Research is timely as we are in a transitional period until the advent of autonomous vehicles. This research has identified the factors that influence the impact of vehicle control algorithms on road transport, depending on technological feasibility, as well as the factors that influence development directions, and then used a questionnaire survey to assess the factors that are most important to society. The correlations between the impacts were analysed and, after identifying the different clusters, this research assessed the opinions of different age groups on the expected impact of self-driving vehicles and the factors influencing their introduction.

Keywords: autonomous vehicles; technology acceptance; impact analysis

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1. Introduction

One of the most important and perhaps most challenging tasks facing the automotive industry today is the research and development of autonomous vehicles. As science progresses, many questions arise about the legitimacy of autonomous vehicles, but this is mostly due to the uncertainty that there are currently no satisfactory answers and no uniformly accepted regulations for the legal, ethical, data protection, and vehicle safety issues that arise. The ever-increasing demand for mobility means that a solution acceptable to all must be found as soon as possible. The technology must be prepared for all possible traffic situations to avoid wrong decisions by the computer, and to this end, tests and measurements are constantly being carried out by research institutes, software developers and automotive companies. Accidents involving test vehicles caused by the software's misjudgements are occasionally reported in the media, but it is important to stress that these collisions contribute to the creation and development of the most perfect and safest system possible [1,2].

Technology is evolving rapidly, and many research groups are working in concert to find reassuring answers to the questions that arise. Autonomous test vehicles in authorised areas have been collecting data for years to assess the most varied traffic situations [3]. The research is timely, as we are currently in a transitional period before the advent of autonomous vehicles, so it is important to have as much information as possible about the likely impact of the technology [4].

Using modern driver assistance systems and autonomous functions requires drivers to acquire new skills to use new technologies effectively and safely. Drivers need to understand the operation of driver assistance systems, their limitations, and the situations in which they operate effectively. However, drivers need not only to be aware of the capabilities and limitations of their vehicles, but also to understand how to integrate these

systems into their everyday driving practices. Systems can improve the driving experience, increase safety, and reduce driver stress, but only if they are used correctly [5,6].

Research shows that autonomous vehicles have a number of expected effects, including reduced traffic accidents, reduced congestion, reduced transport-related costs, reduced following distances between vehicles, and reduced parking space requirements in cities; autonomous vehicles would help elderly people and children to travel independently and would make more efficient use of time spent on transport [7,8].

The development of autonomous technologies is influenced by a number of factors, from the technological implementation, through the social acceptance of these systems, to the integration of solutions into the transport system. The different autonomous levels (e.g., on a scale from 1 to 5) indicate how advanced a vehicle's self-driving capability is. Developing higher levels of autonomous vehicles requires more technological innovation, which requires significant research and development resources, including in the fields of artificial intelligence, machine learning, sensor technology, and computer vision. However, the development of higher autonomous capabilities not only poses technological challenges, but also raises regulatory and ethical issues. The market introduction of fully self-driving vehicles will require extensive legal and regulatory changes, including liability and safety regulations. In addition, consumer confidence and social acceptance will become a key factor as fully autonomous vehicles radically change driving and transport habits [9,10].

The safe, accident-free operation of vehicles equipped with current driver assistance systems, as well as vehicles with semi-autonomous functions, could be a key factor for the acceptance of autonomous vehicles. The number of accidents caused by these systems is critical for the autonomous vehicle industry as a whole, influencing consumer confidence, regulatory policy, and thus, indirectly, the direction of autonomous vehicle technology development and the transformation of the automotive industry and the economy [11,12]. The frequency of failure of the sensors responsible for the operation of autonomous vehicles influences the reliability and maintenance costs of vehicles, which indirectly affects the market and social acceptance of autonomous technologies. Failure of these sensors poses significant safety risks, especially in situations where the vehicle relies entirely on these sensors for navigation and decision-making [13,14].

The cost of sensors such as lidar, radar, camera, and ultrasonic sensors needed to detect and operate autonomous vehicles directly affects the market competitiveness, availability, and potential for the development of autonomous vehicles. Because of the high costs, manufacturers are constantly looking for more efficient and cheaper sensors, as well as alternative technologies such as camera- and AI-based systems. This process is driving technological innovation as manufacturers seek new solutions to reduce costs and increase reliability. With high production costs, the price of autonomous vehicles can increase significantly, which may limit their availability to a wide range of consumers. This is particularly important in the passenger car market where price is a sensitive factor. Manufacturers should therefore develop strategies to reduce costs to make autonomous vehicles more accessible to the mass market [15,16].

The regulatory environment has a significant impact on the market uptake of autonomous vehicles. Strict regulation can slow down the spread of the technology, while a supportive legal environment can accelerate it. For example, in some countries, government subsidies and looser rules for testing autonomous vehicles may facilitate technological development and market uptake, but stricter safety standards may increase consumer confidence. Increasing consumer confidence is critical for market success as it will encourage consumers to buy and use autonomous vehicles [17].

The aim of this study is to assess, from a societal perspective, the various technological aspects and development directions that contribute to the promotion of social acceptance of driver assistance systems and autonomous functions. The novelty of this study is the assessment of the opinions and positions of different groups in society on the above-mentioned issues, and to what extent they agree with these statements. All these have a decisive influence on the development of the automotive industry and the economy.

The following chapters describe the methodology of the survey and the evaluation of the data collected during the research. The research carried out in this article only reflects the views of the target groups who filled in the questionnaire, so no uniform conclusions can be drawn for society as a whole.

2. Materials and Methodology

The literature review identified the factors that may influence the adoption and purchase of autonomous vehicles. Based on the literature, the impact of autonomous vehicles on transport was also defined, and a questionnaire was compiled to assess which factors are considered to be of high and low importance by different groups in society. The questionnaire was available online to ensure the widest possible participation in the survey. A total of 96 people completed the survey questionnaire. The statements elaborated in the questionnaire were refined on the basis of in-depth interviews with experts, in addition to a literature review. Through the interviews, the qualitative research method aimed to complement the literature with the experiences of the interviewees. The information and practical experience gained from the expert interviews were incorporated into the survey, thus directly contributing to the relevance and accuracy of the questionnaire, ensuring that the statements are a true representation of the real situation and meet the objectives of the research. In order to systematise the many input factors, it was necessary to perform a principal component analysis, whereby parameters that are closely correlated with each other could be combined into a few principal components as a linear combination. The relationships and correlations between the variables were analysed, taking into account the data and information on the driving habits and demographic characteristics of the respondents. A significant focus of the analysis has been on examining the correlation between the data to identify which factors are highly correlated and which are less so. Using this method, a data structure was developed and the relationships and patterns between the variables were identified, the results of which are presented in the next chapter. The analysis was performed using IBM SPSS software (29.0.2.0).

3. Results

3.1. Demographic Analysis

The survey was completed by 96 people, 51% of whom were women and 49% men. In terms of age, 57.3% of respondents were aged 18–24, 14.6% were aged 25–34, 9.4% were aged 35–44 and 11.5% were aged 45–54. A smaller proportion of older respondents completed the questionnaire. Those aged 55–64 accounted for 5.1% of respondents, while those aged 65 and over accounted for 2.1%. The questionnaire identified the age of the vehicle of the respondents.

Table 1 shows the age distribution of the participants' cars; 25% of the participants do not own a vehicle and almost half of them, 45.7%, have a vehicle that is more than 8 years old. Only a small proportion of participants own a new car.

Table 1. Age of the vehicle of those completing the survey.

Vehicle Age	Percentage Distribution
less than 1 year old	2.1%
1–2 years old	3.3%
2–4 years old	4.3%
4–6 years old	8.7%
6–8 years old	10.9%
the respondent does not own a car	25%
Over 8 years old	45.7%

The research also assessed how often respondents drive or travel in cars.

Table 2 illustrates the car use habits of the participants. More than half of the participants (51%) travel by car every day. A further 33.3% drive or travel by car several days a week.

Table 2. Frequency of car use.

Frequency of Car Use	Percentage Distribution
Every day	51%
Few days a week	33.3%
Few days a month	13.5%
More or less never	2.2%

3.2. Analysis of the Correlation Between Attitudes Towards Technological Innovation and Knowledge of Driver Assistance Systems

This research compared the correlation between the attitude of survey participants towards technological innovation and their knowledge of driver assistance systems (autonomous vehicle functions). The 5-point Likert scale was used for the attitude statements. The results are presented in Table 3.

Table 3. Correlation between technological attitudes and management support systems.

		How Knowledgeable Do You Feel You Are in the Field of Advanced Driver Assistance Systems in General?
Pearson Correlation	TA1 [1]	0.422
	TA2 [2]	0.362
	TA3 [3]	0.433
Sig. (2-tailed)	TA1 [1]	<0.001
	TA2 [2]	<0.001
	TA3 [3]	<0.001

[1] Attitude to technology—I like new technologies and I am among the first to try and use them. [2] Attitude to technology—I know more about the latest technologies and products than others. [3] Attitude to technology—I often buy new technology products, even if they are expensive.

The analysis shows that there is a moderately strong correlation between attitudes towards technological innovation and knowledge of driver assistance systems among respondents, with a significance level < 0.001 for all questions. This suggests that those who are generally more interested in technological novelty are also more open to driver assistance systems, but there is no strong relationship. Thus, even for those social groups who are more interested in new technological solutions, it is necessary to demonstrate autonomous functions. For people less open to technology, this is particularly important.

The TA1, TA2, and TA3 attitude statements were examined among respondents who use/drive a car every day. No significant differences were found between the responses. The mean values of the responses to the statements are shown in Table 4. There is therefore no significant difference in knowledge of driver assistance systems between those who use a car every day and those who do not.

Table 4. Relationship between car use and knowledge.

	Frequency of Car Use Every Day	Frequency of Car Use Less Often Than Daily
TA1	3.22	3
TA2	2.9	2.8
TA3	2.79	2.55

3.3. Analysis of Factors Influencing the Purchase of Autonomous Vehicles

The research identified the factors that strongly and weakly influence the purchase of autonomous vehicles, which presented in the Table 5.

Table 5. Analysis of factors influencing the purchase of autonomous vehicles.

	PI1 [1]	**PI2** [2]	**PI3** [3]	**PI4** [4]	**PI5** [5]	**PI6** [6]	**PI7** [7]	**PI8** [8]	**PI9** [9]
Mean	2.82	2.83	3.05	2.98	3.19	2.29	2.84	3.11	2.36
Median	3.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	2.00
Mode	3	2	3	3	3	1	3	3	3
Std. Deviation	1.223	1.176	1.191	1.133	1.199	1.151	1.182	1.178	1.125

[1] With a higher level of automation, I would rather buy a self-driving vehicle. [2] I would prefer to buy a self-driving car if the cost of the built-in sensors is lower. [3] I would rather buy a self-driving vehicle at a lower price than a conventional vehicle. [4] In the rare event of a sensor failure, I would prefer to buy a self-driving vehicle. [5] I would prefer to buy a self-driving vehicle once the requirements for its use (principles of use, liability, cybersecurity) have been clearly defined. [6] I would like to buy a self-driving vehicle as soon as it is commercially available. [7] I would prefer to use a self-driving vehicle as part of a car-sharing service. [8] If accidents, congestion and environmental pollution were reduced, I would prefer to buy a self-driving car. [9] I would still buy a self-driving vehicle despite the accidents caused by self-driving vehicles.

Based on the analysis, it can be concluded that in the future, the purchase of autonomous vehicles will be determined by the price of the vehicles and the reduction in accidents, and that the greatest need for clarification of legal issues and regulations will be the purchase of autonomous vehicles from the point of view of society. The level of automation is less input–output, so there would be a demand for vehicles with less knowledge requirements but that are cheaper and safer. The fact that consumers would only buy vehicles on the basis of positive experiences and malfunctioning could be a clear disincentive to take up the vehicles. Less use would be made of car-sharing services, so it could be argued that people would have more confidence in autonomous vehicles that they own.

4. Discussion and Conclusions

Indeed, many challenges and unresolved issues must be counteracted before the widespread use of autonomous vehicles; in addition to solving technological problems, social divisions, uncertainties over responsibilities, and fear of untested technology and hacker attacks are among the issues to be addressed. There are many difficult decisions to be made, but overcoming these obstacles is expected to lead to a much safer transport system.

The implementation of driver assistance systems and autonomous vehicles requires perseverance, decades of research, and countless tests, but it is all worth it, as these technologies prevent accidents and save lives on the road.

In the present research, a questionnaire survey was used, the results of which revealed a relationship between the level of knowledge about ADAS systems and technological acceptance. Furthermore, with a mean score of 3.19, it was important for the participants to have a clear definition of the requirements for using a self-driving vehicle in relation to their intention to purchase. One of the main limitations of the research is that the sample size is relatively small, which is worth increasing in future research, and further links may be worth exploring to better understand consumer attitudes.

Society needs to be open to automotive innovation and new transport options, as no system or service can work without users. Transport users of different ages and cultures, with different technological skills, also make it difficult to achieve a coherent system that is clearly the most efficient and easy to use and understand for everyone. In order to ensure that pedestrians, cyclists, and road users feel safe today and to speed up the social acceptance of autonomous vehicle control technologies, it is absolutely essential to carry out the research and survey described in this article. In summary, the social acceptance of

autonomous vehicles and the directions of their development, as well as the building of trust in the technology, are influenced by a number of complex and interrelated factors.

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