Technical risks and social trust in the adoption of self-driving vehicles: an analysis of safety challenges and cyber threats

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Abstract: The technological development of self-driving vehicles opens up new horizons in transport, but also reveals complex technical and societal risks. This study investigates the relationship between accident risks, cyber threats and technological distrust based on empirical research (n = 1840). The results show that high levels of technical anxiety - in particular uncertainty around cyber security, system failure and autonomous decision-making - significantly reduce users' subjective sense of safety. Social acceptance of technology is thus determined not only by engineering performance but also by public attitudes. The study highlights the importance of safety-oriented engineering, transparent regulation and user education for the future successful integration of autonomous vehicles.
Keywords cybersecurity, self-driving vehicles, technical concerns, social trust, road safety, road safety

1 Introduction

The proliferation of self-driving vehicles is bringing about a major technological and societal transformation, affecting not only the automotive industry but also people's daily lives. The aim of this paper is to explore the opportunities and challenges associated with self-driving technologies, with a particular focus on ethical, safety and technological issues. Although semi-autonomous vehicles are becoming more widespread, social acceptance is still low, mainly due to fears about safety, especially among women. Trust in self-driving systems is affected by factors such as fear of hacking attacks or loss of control. In contrast, supporters stress the reduction of traffic accidents and the environmental benefits. The findings of this paper can provide important guidance to technology developers and policy makers for the successful integration of self-driving vehicles into future transport systems [4, 11, 14, 15, 18].

Technological progress, in particular the emergence of self-driving cars, has a mixed reception in society. One of the reasons for resistance to technological innovation is technostress, which can manifest itself as psychosocial strain resulting from the use of digital technologies, especially in the workplace. Although clear data on the effects on mental health are not yet available, research suggests that well-organised digital work can increase flexibility, worker control and autonomy, and thus may even have positive effects. Digital work can therefore have a double effect: it can be both an opportunity and a risk. To understand the social acceptance of these technologies, it is essential to analyse user attitudes and to clarify ethical and legal issues so that these innovations can be safely integrated into everyday life [13, 16, 19].

The technology for self-driving vehicles is already available, but there are still a number of challenges that hinder their widespread uptake. Lack of confidence, high prices, legal and ethical issues are slowing down uptake. Of the six levels of autonomy, only the lower levels are widespread, while full self-driving (level 5) is still under development. In the US, progress is faster, while in the EU legal barriers such as the Vienna Convention need to be modified. Fears about technology, especially about the transfer of control, are putting many people off. Demographic factors, such as age and education, also influence adoption. Most people are not in favour of fully autonomous vehicles, but would prefer partial automation. Car manufacturers and developers should therefore take user concerns into account and increase social acceptance by developing transparent, safe systems [15, 18, 24, 25].

Research shows that although self-driving car technology is now available, the majority of people still have a lack of confidence in it. Key concerns include high cost, reliability and fear of losing control. However, many people are positive about the convenience and enjoyable driving experience, especially if they do not have to pay more for it. The use of technology in public transport is more widely accepted, as there is less emphasis on personal control. Research highlights that trust is a key factor in the uptake of self-driving cars and its lack is a barrier to social acceptance. The sense of vulnerability of users and the fear of losing control over technological decisions also raises ethical and social questions. Developers must therefore take human factors into account if they want to increase the acceptance of autonomous vehicles [4, 14, 15, 18, 19].

The development of self-driving cars raises serious ethical and safety challenges. One of the key dilemmas is how cars make decisions in inevitable accident situations - for example, when the lives of passengers may be at stake versus those of pedestrians. Research shows that people prefer to minimise casualties, but this view often changes when they imagine themselves in the car. Ethical decision-making and continuous updating are essential when developing software. In addition, cybersecurity is a key issue: self-driving systems can be hacked, which poses serious risks. Technology adoption depends largely on trust in security and transparent communication. People tend to reject technology if they do not understand how it works or feel threatened. Therefore, manufacturers need to focus not only on technical improvements, but also on educating users and increasing their sense of security [2, 3, 9, 10, 23, 26, 30].

1.1 Sensors and central unit for self-driving vehicles

In the development of self-driving vehicles, sensors that enable accurate sensing of the environment and autonomous decision-making are a key element. One of the most important sensors is LiDAR, which uses laser pulses to create a three-dimensional map of the vehicle's environment, providing highly accurate and detailed information. Although extremely useful, LiDAR is sensitive to weather conditions such as fog or rain and comes at a high cost. Radar measures the reflection of radio waves, allowing distance and speed to be determined even in adverse weather conditions. However, it has a lower resolution and therefore provides less detailed information on the shape of objects. The cameras capture visual data, which are processed by image recognition algorithms to enable object recognition and banding, but their performance is highly dependent on lighting conditions. Ultrasonic sensors measure distance over short ranges using sound waves and are mainly used for parking assistance, but their accuracy can be affected by surfaces due to their short range [1, 5, 6, 7].

The vehicle's central unit plays a key role in ensuring autonomous driving by processing the data provided by sensors and building up a comprehensive picture of the environment. The central unit fuses the incoming data and then interprets the environment, identifies objects and determines their position, speed and direction of movement. Based on this information, it makes decisions about the vehicle's behaviour, such as turning, speed, lane change, acceleration or braking[5, 6, 28].

The central unit converts the decisions into control signals that are sent to the vehicle's various actuators, such as the steering, brake and accelerator, to perform the desired manoeuvres. The system continuously monitors the environment and can activate emergency protocols if necessary, for example in the event of sudden obstacles to avoid accidents [1, 5, 7, 28].

The central unit could also be responsible for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, which can contribute to increasing the safety and efficiency of transport. The central unit of a self-driving vehicle is therefore responsible not only for sensing but also for control and communication functions, and the complexity of the system requires the cooperation of several computing units, such as CPU, GPU and FPGA, to perform these tasks efficiently [1, 6, 7, 12, 21, 31].

Sensor type	Operating principle	Benefits	Disadvantages	Typical application
LiDAR	3D imaging of laser pulses	High accuracy, detailed 3D information	High cost, sensitivity to weather conditions (e.g. fog, rain)	Environmental sensing, object detection, mapping
Radar	Measuring the reflection of radio waves	Works well in bad weather conditions, distance and speed measurement	Lower resolution, less detailed object shape information	Distance measurement, speed measurement, obstacle detection
Camera	Capturing and processing visual information	Rich information content, cheaper than other sensors	Performance depends on lighting conditions, complex image processing required	Object recognition, lane keeping, traffic sign recognition
UH sensor	Measuring the reflection of sound waves (short distance)	Cheap, simple implementation	Short range, accuracy may be affected by surfaces	Parking assistance, proximity obstacle detection

Table 1

Comparison of Sensors Used in Autonomous Vehicles by Operating Principle, Advantages, Disadvantages, and Typical Applications

1.2 Dangers of self-driving cars

The rise of autonomous vehicles offers many opportunities to improve transport safety, but also poses serious challenges, in particular with regard to accidents and terrorism. The use of self-driving technology can significantly reduce the number of accidents caused by human error, but it also brings new types of threats, such as cyber security risks or the possibility of terrorist acts.

In terms of accidents, self-driving vehicles offer a significant improvement through advanced detection and response systems. The technology can reduce human error caused by factors such as inattention, fatigue or drink-driving. However, system failures, weather conditions, data security and testing challenges can still be a barrier. Research in recent years has shown that accidents involving self-driving cars are often caused by the limitations of the technology and unexpected traffic situations [16, 22]. Such incidents have a negative impact on public perception, which is a key factor in the uptake of autonomous vehicles [22]. According to the US Department of Transportation, continued development of safety protocols and proper testing of autonomous systems is essential for widespread adoption of the technology. In addition, a comprehensive analysis of accidents involving self-driving cars is key to determining the direction of future developments [5].

Self-driving vehicles could be a new threat for terrorism. Modern technology allows autonomous systems to become tools for attacks that can be controlled remotely.

The risk of cyberterrorism is also a prominent concern in the context of self-driving vehicles, as malicious hackers may be able to take control of some vehicles, causing accidents or targeted attacks [20, 23, 29]. Former FBI Director Keith Lourdeau has also pointed to the growing role of autonomous systems as a tool for cyberterrorism, which could destabilise society. According to a 2021 NATO report, autonomous technologies could pose security risks not only in transport but also in military and strategic infrastructures. Furthermore, an international report suggests that the increase in cybersecurity threats suggests that autonomous vehicles could be potential targets for future terrorist attacks [17, 23].

As technology evolves, it is crucial to develop appropriate regulation and security measures. According to the principle of Manful Human Control (MHC), developers and programmers must also take responsibility for the security of the autonomous systems they create [2]. This includes continuous monitoring, anticipating potential threats and adhering to ethical development practices. There is also a need to strengthen international regulation to reduce the risk of cyberterrorism and inappropriate use of self-driving cars [2, 10, 26, 23].

The European Union Agency for Cybersecurity also stresses that the protection of autonomous systems should be a top priority in the coming years [29]. In conclusion, the risks of self-driving cars, both accidental and terrorism-related, deserve attention. While the technology has the potential to improve road safety, it can also pose serious risks in the absence of appropriate regulation and security measures. The responsibility of programmers, strengthening cybersecurity measures and public awareness are key steps to ensure that autonomous vehicles can be deployed safely and widely. Future research and technological developments should focus on minimising the safety challenges of self-driving vehicles and contribute to a more stable and sustainable transport system [3, 8, 27, 2, 17].

2 Data and methodology

Data was collected through an anonymous online questionnaire, which allowed respondents to express their opinions honestly, thus increasing statistical reliability. The online questionnaire format provided a quick and convenient way to collect and analyse the data. While the voluntary nature of the respondents and the convenience sampling method do not guarantee a fully representative sample, the large number of respondents (1 840) already provides a strong basis for the reliability of the survey results and helps to ensure that the conclusions are valid for a wider audience.

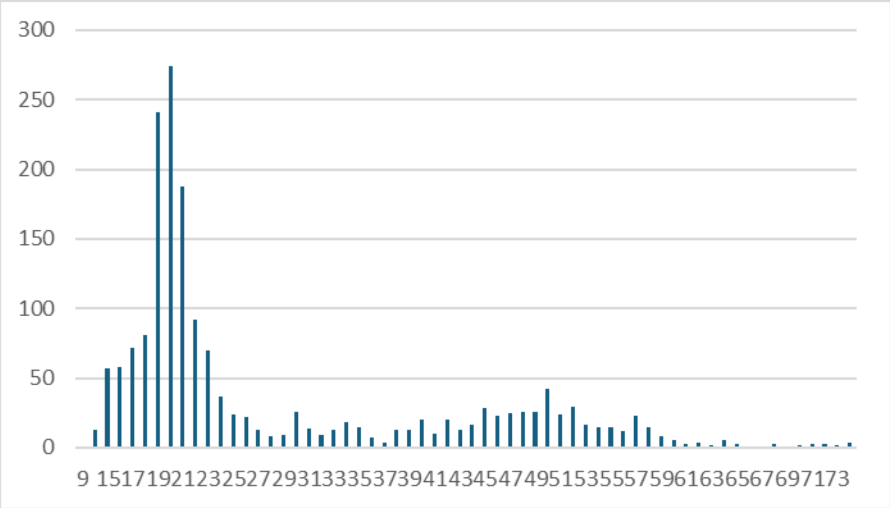

Figure 1
Age distribution of respondents (n=1840)

The aim of the research was to investigate the social acceptance of self-driving cars in particular. The results will contribute to a better understanding of the topic and may provide useful guidance for future research. The age of the respondents ranges from 9 to 75 years, with a mean age of 28.49 years and a median of 21 years, and a standard deviation of 13.819. The mean age is higher than the median, suggesting that more respondents were younger, but the wide age distribution shows that the questionnaire addressed several age groups, allowing a detailed analysis of different aspects of social acceptance.

The results of the survey, although not representative, can provide important insights into the evolution of public opinion and contribute to a better understanding of the social acceptance of future self-driving vehicles.

The research explored attitudes towards self-driving technologies along eight targeted questions covering perceived challenges, risks and potential uses of autonomous vehicles. The dimensions surveyed provide a comprehensive picture of respondents' views on both civilian and military applications. The following variables formed the basis of the analysis:

- Biggest technological challenge: The question aims to find out what respondents consider to be the biggest technological challenge in the development and deployment of self-driving vehicles. The responses will help identify the main barriers limiting technological adoption.
- Cybersecurity of self-driving cars: This question explores concerns about the cybersecurity risks of self-driving vehicles. The answers provide an

indication of the extent to which respondents feel vulnerable to hacking and unauthorised access.

- Communication between drivers and pedestrians: This question measures the importance respondents attach to the establishment of effective communication between self-driving vehicles and human road users. This issue is particularly relevant in the context of urban transport, where implicit human interaction is common.
- The need for regulation: This question addresses the need for a regulatory framework for autonomous vehicles. Respondents express their views on the importance for them of regulating responsibility, ethics and safety at the level of legislation.
- Most challenging traffic environment: This question asks respondents which traffic environment (e.g. city, motorway, extreme weather) they consider most challenging for self-driving systems. The results highlight socially perceived technological barriers.
- Combat use of self-driving military vehicles: This question explores societal attitudes towards the use of autonomous vehicles for combat purposes in the military. It focuses on the acceptability of military decision-making without human intervention.
- Most suitable military tasks for self-driving vehicles: This question explores which military tasks (e.g. logistics, reconnaissance, surveillance, combat) respondents consider most suitable for autonomous vehicles. The results contribute to the societal perception of autonomous military technology developments.
- Likelihood of terrorist use: This question assesses the extent to which respondents fear that self-driving vehicles could be used for malicious purposes, such as terrorist attacks. The answers reflect societal perceptions of the technological threat.

4 Results and discussion

For the analysis, two composite indicators (indices) were first developed: the technical concern index and the security perception index. The technical concern index was composed of four variables representing different dimensions of technological risk perception: (1) fear of cybersecurity threats, (2) likelihood of failure of self-driving vehicles, (3) lack of possibility of human intervention, and (4) concerns about the security of personal data. By averaging these variables, an aggregate variable was created that reflects the extent of an individual's lack of confidence in technology. The perception of safety index was composed of perceptions of safety for different levels of automation (from full human control to full autonomy) of self-driving vehicles, also averaged.

		Levene's Test for Equality of Variances		t-test for Equality of Means								
											95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference		Std. Error Difference		Lower	Upper
biztonsag index	Equal variances assumed			1,453	0,230	0,243	188	0,809	0,02544	0,104 82	-0,18134	0,23222
	Equal variances not assumed			0,225	77,97 8	0,823	0,02544		0,11306		-0,19965	0,25052

Figure 4

Independent sample t-test to examine differences between perceptions of safety and technical concern

The first step in the statistical analysis was an independent samples t-test, which examined differences in perceptions of safety between two groups (low and high technical concern). Three categories were then created based on the level of technical concern (low, medium, high), and a one-factor analysis of variance (ANOVA) was used to test whether there was a statistically significant difference in mean safety perceptions between them.

ANOVA

security_index

	Sum of Squares	df	Mean square	F	Sig.
Between Groups	9,423	2	4,712	8,784	0,000
Within Groups	985,317	1837	0,536		
Total	994,740	1839			

Table 2

Comparison of means of the safety perception index between different levels of technical concern using one-way analysis of variance (ANOVA)

Since the condition of homogeneity of variance was not met (Levene's test: $p < 0.05$), the Tamhane post hoc test was used to interpret the differences between pairs of groups. The analyses aimed to determine the extent to which attitudes towards technological risks influence the social acceptance of self-driving technologies, in particular the development of the perception of safety.

Multiple Comparisons

Dependent variable:

Tamhane

(I) concern_group		Mean Difference (I-J)	Std. Error	Sig.	95% confidence interval	
					Lower Bound	Upper Bound
1,00	2,00	-0,04536	0,04242	0,635	-0,1468	0,0561
	3,00	,12224*	0,04380	0,016	0,0175	0,2270
2,00	1,00	0,04536	0,04242	0,635	-0,0561	0,1468
	3,00	,16760*	0,03928	0,000	0,0737	0,2615
3,00	1,00	-,12224*	0,04380	0,016	-0,2270	-0,0175
	2,00	-,16760*	0,03928	0,000	-0,2615	-0,0737

*. The mean difference is significant at the 0.05 level.

Table 3

Pair-wise comparison of the safety perception index using the Tamhane post hoc test between different levels of technical concern

The results of the statistical analyses supported the initial hypothesis that the level of technical concerns affects the subjective perception of the safety of self-driving vehicles. The analysis first used an independent samples t-test to compare two groups of respondents with low and high technical concerns. However, the t-test did not show any significant difference in the perception of safety between the two groups, and the hypothesis was not confirmed in this form. For a more detailed analysis , after categorising the respondents into three groups based on their level of technical anxiety, a one-factor analysis of variance (ANOVA) was performed. The ANOVA results indicated a significant difference between the means of the three groups in terms of safety perception. The inequality of variance revealed by the Levene test necessitated the application of the Tamhane post hoc procedure, which revealed that members of the high anxiety group reported significantly lower feelings of safety than members of the medium or low anxiety groups. In contrast, there was no significant difference between the low and medium groups. Overall, the results show that perceptions of technological risks, in particular cyber security, system failure and uncertainty related to autonomous decision-making processes, have a negative impact on subjective attitudes towards the safety of self-driving vehicles. This finding highlights the role of technological confidence and technical risk perception in the social acceptance of autonomous systems

Conclusions

The rise of self-driving vehicles is both a technological breakthrough and a new type of risk to road safety. The aim of this study is to examine societal perceptions of technical concerns and safety perceptions related to self-driving technology, with a particular focus on the challenges posed by accidents and cyberterrorism. The quantitative research is based on an online questionnaire survey of 1840 respondents covering a wide age range (average age: 28.5 years).

Among respondents, ambivalence about trust in technology was particularly high, with a significant proportion of respondents sensitive to the idea of system failure, cyber threats and lack of human control. Two composite indicators - the technical anxiety index and the security perception index - were constructed and the relationship between them was examined using statistical analysis. Although the first t-test did not confirm a significant difference between the low and high concern groups, ANOVA and Tamhane's post hoc test showed that the high concern group had significantly lower perceptions of security.

The results suggest that the subjective perception of technical risks has a direct impact on the social acceptance of self-driving vehicles. The perception of safety is not only a technological issue, but also a social and psychological construct. The study stresses that strengthening technical reliability, user education and a transparent regulatory and safety framework are essential for the development of autonomous transport in the future.

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