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Safety of autonomous vehicles: what are the insights from experienced industry professionals?

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ABSTRACT

Many drivers support the push towards the automation of transportation. Technology and automotive companies, the general public, and governments are all seen as the main groups pushing the automation revolution forward. The key to this revolution's success will rest with the perception of the professionals in the field as their perception will affect the way that Autonomous Vehicles (AVs) are adopted. This study surveyed 185 experienced industry professionals to gather their comments and opinions on AVs' purported safety benefits and drawbacks. The results in this paper illustrate that the 'incorrect understanding of the surrounding objects by AVs' could be the most significant technical concern and may lead to accidents. Some professionals had concerns about trusting the AVs' safe operation without steering wheels, while some others believed that there is a chance that having steering wheels may increase safety concerns. The findings also suggest that while AVs might reduce the number of accidents, this may not necessarily be the case for the severity of any accidents. The severity may remain unchanged or even increase as a result of the adoption of AVs. This paper's results show that the majority of the professionals consulted agreed that AVs have the potential to increase road safety significantly. However, the consensus was that more research and testing is needed in this field.

1. Introduction

Issues on the safety of AVs have been shown to be the greatest benefit but also the greatest concern (Kim, Park, Oh, Lee, & Chung, 2019). Safety is often cited as one of AVs' main concerns while also being the main reason for users adopting AVs (Chan, 2017). The Organisation for Economic Co-Operation and Development (OECD) has estimated that the total motorised mobility in cities will have risen by 94% in 2050, reaching 34.9 billion passenger-kilometres (BPK). This is compared with 18 BPK in 2015 (OECD, 2017). As a result of the rise in the demand for mobility, road safety has become a significant global public health issue. Road accidents are estimated to be the number one cause of death among young people aged 15–29, and the data show that more than 1.2 million people die in global road crashes each year (OECD, 2017). Favarò et al. (2017) indicated that about 94% of car accidents occur due to human driver errors. Fagnant and Kockelman (2015) verified this statement by statistically representing that accidents related to passenger cars are mostly the result of driver errors relating to problems such as alcohol, distraction, drug involvement, fatigue, speeding, and drowsiness, all of which are human errors and would be eliminated in AVs; however, Liu et al. (2020) argues that controlling safety functions will have yet to remain AV driver's responsibility. Several studies have investigated the possible safety benefits and drawbacks of AVs. Bansal, Kockelman, and Singh (2016) showed that the ability to forecast vehicles' movements in a fleet provides

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safer and smarter mobility due to a more efficient connection with other cars. Besides this, the better enforcement of the law could be applied to speed limits as AVs adhere to driving rules and do not violate them. The result would be a safer transport system (Howard & Dai, 2014). Fagnant and Kockelman (2015) found that AVs can anticipate other vehicles' reactions, such as unexpected braking and any decision to accelerate. As AVs would have a better route choice capability, they could use the road lanes more efficiently. Subsequently, the AVs will operate with shorter gaps between them and other vehicles in the platoon. This ability provides better control of the vehicle for safer and smoother braking operations and better adjusts the vehicle's speed in the platoon (Fagnant & Kockelman, 2015). Interestingly, recent research in this field suggests that safety concerns may be linked to public acceptance and as the numbers of AVs on our roads increase that these safety concerns will ease (Taeihagh & Lim, 2019).

AVs may be more alert than human drivers (Howard & Dai, 2014). Papadoulis, Quddus, and Imprialou (2019) and Vander Laan and Sadabadi (2017) pointed out the safer driving operations of AVs compared to human drivers as a result of the AVs' quicker reaction time. Noy, Shinar, and Horrey (2018), Tabitha, Sandt, Clamann, and McDonald (2018), and Matsumi, Raksincharoensak, and Nagai (2013) indicated that AVs would be very safe through acquiring smart sensors that help to avoid collisions with pedestrians. These could also assist the AVs in making informed decisions about upcoming traffic. Kyriakidis, Happee, and De-Winter (2015) pointed to the AVs' safety as a result of removing human errors, and the research by Howard and Dai (2014) supports this statement by indicating that AVs can reduce the number and severity of accidents that occur as a result of the errors in human driving operations due to problems such as drinking, using drugs, distraction, and fatigue behaviours. The safe identification of surrounding objects such as humans and animals has been introduced as another safety benefit of adopting AVs (Katrakazas, Quddus, Chen, & Deka, 2015). Moreover, AVs are claimed to provide safe mobility for the elderly, disabled people, and unlicensed drivers, and even delivering freight (Beirigo, Schulte, & Negenborn, 2018; Chan, 2017).

It is imperative to say that the Society of Automotive Engineers (SAE) defined six levels of automation for AVs¹, which have also been adopted by the National Highway Traffic Safety Administration (NHTSA). Please see the NHTSA (2019) and SAE (2018) for the definition of each level. This study aims to evaluate AVs' safety at the ultimate level of automation (i.e., level 5, which is also referred to as full automation) in the context of the road network. Therefore, the term 'AV' throughout this paper represents a fully automated car or level 5 AV.

The main objective of the paper is to examine the safety concerns of adopting AV's. An experienced industry professional panel survey was conducted which consisted of academics and industry professionals to ascertain their perceptions of any safer issues with AV's. Our paper is one of the first to use such an experienced industry professional to examine this topic as opposed to a survey of the general public. This different focus of sample provides a contribution to the debate in this field. While every effort was made to ensure that the responses to our survey were from experienced industry professionals, a caveat should be noted in that the responses were not all from experts in the field of AVs and their impacts upon safety. Moreover, they were professionals in the transportation field that have seen many technology advances and their opinions were sought on how this new technology advance could impact upon road safety.

The organisation of the paper is as follows. Section 2 reviews the literature in the field. Section 3 discusses the methods used for the evaluation of this study, namely the data collection method, the demographics of the survey sample, and the discussions about the method of analysis and tools adopted for the statistical evaluations. Section 4 includes the correlational assessments of the survey data and highlights the main findings related to the impact of some of the technical issues that may impact the number and severity of accidents. The final section discusses the key findings of the survey and situates them in the literature. It then provides some guidelines for future research in this area.

2. Literature review

2.1. Testing and operation of AVs

In order to ascertain whether AVs are safe enough to operate on public roads, they need to be tested in real road traffic situations. Although there has been some advanced modelling to assess AVs' collision risk as part of predicting dangerous situations that may be prone to accidents, there is still a need for legal frameworks for testing AVs in real situations (Katrakazas, Quddus, & Chen, 2019). Many attempts have been made to put together legal frameworks for the testing of AVs' safe operations; there have been some advancements in this regard too. For example, the Governor of Massachusetts signed an executive order in October 2016 to promote the testing and deployment of autonomous driving technologies (NCSL, 2016). NHTSA issued updated guidance for the safe development of AVs, announcing that the US states need to retain their traditional responsibilities for vehicle licensing, traffic laws, enforcement, insurance and the vehicle's liability framework (NHTSA, 2016). There have been more advancements in AV legislation, testing operations, and research and deployment policies, which helps in terms of the practical functionality of AVs on public roads and their possible impact on road transport (Bruyne & Werbrouck, 2018). Imai (2019) stated that there had been some recent revisions to Japan's road transport and traffic regulations to improve the legal framework for the operation of Level 3 AVs on public roads. Wang and Li (2019) stated that AVs' testing has already been started in the US, Europe, and Asia. Maybe the most promising reports on the advancements of the AV regulations could be seen in the recent studies conducted by Lee and Hess (2020) and Costantini et al. (2020). They studied various safety regulations and data protection frameworks for use in the road testing of AVs. In the study conducted by

¹ Level 0 (L0): No Automation, L1: Driver Assistance, L2: Partial Automation, L3: Conditional Automation, L4: High Automation and L5: Full Automation.

Lee and Hess (2020), Victoria, Australia, and Germany required a safety driver for the road testing of AVs while California did not. The study by Lee and Hess (2020) showed the regulations regarding safety management, the recording and reporting of data and the liability of the AV under road testing operations. Costantini et al. (2020) showed that many countries have already updated their legal regulations regarding data protection and management for AVs' safe testing and operation. This is an advancement concerning the AVs' legal framework. However, until reaching a unified legal framework that permits the testing and operation of AVs on the street alongside other human-driven vehicles in all countries, the industry and academia might be able to take some steps to identify the possible risks and benefits of these vehicles in the transport system. In this regard, survey studies are an easy and feasible investigation method that can collect the thoughts and feedback of public individuals, engineers, and researchers from a diverse range of expertise. Some survey investigations have been previously conducted to assess the safety benefits of AVs.

2.2. Safety survey studies

To date, few surveys take into account experienced industry professionals' views as they are written for public individuals, especially the surveys with a focus on safety. This is a gap in the AV research that the current paper is aiming to fill by presenting the results of a professional survey which may help to advance the knowledge in this area of research. Nevertheless, the results of the public surveys in this area are still helpful as they may provide proof of the materials provided by the professionals in the field.

Liu, Nikitas, and Parkinson (2020) conducted an expert survey to investigate the diverse dimensions of user acceptance of AVs, focusing on privacy and cybersecurity, which will also impact AVs' safety. The experts in their study found safety as one of the primary factors impacting the adoption of AVs.

Alghuson, Abdelghany, and Hassan (2019) surveyed 1418 experts and public individuals in multiple countries. They used Binary logistic regression to analyse the survey results; their investigation revealed that AVs would enhance traffic safety. The results of a survey study by Qu, Xu, Ge, Sun, and Zhang (2019) on 1453 public individuals in China revealed that AVs might be beneficial when the human drivers are in poor conditions like alcohol, drugs, and medications. Hulse, Xie, and Galea (2018) surveyed 925 public individuals in the UK. Hulse et al. (2018) used Multinomial Logistic Regression (MNL) to analyse the survey results. Their investigations revealed that AVs would have a low risk of accidents compared to human-driven vehicles, making AVs much safer to operate. A reduction in the number and severity of accidents was also a finding of several other studies.

In a study conducted in the US and Germany in 2015 named Continental (2015), a total of 4100 public individuals and transportation experts were studied related to the benefits and drawbacks of adopting AVs. Preventing serious accidents was found to be the main benefit of AVs that verified the result of an expert survey study conducted by Underwood (2014).

Bansal et al. (2016), Howard and Dai (2014) and Casley, Jardim, and Quartulli (2013) conducted surveys in the US. They adopted statistical methods such as Probit, Logit, and ANOVA, respectively, to analyse the safety benefits of AVs' application on public roads. Their studies also consolidated the results of the previous survey studies by pointing to the reduction in accidents and the increase in the level of road and individual safety as the main benefit of adopting AVs. 'Quicker response than human drivers' and 'fewer accidents with less severity' were also highlighted in two surveys with a total of 3100 participants from multiple countries in the studies conducted by Schoettle and Sivak (2014a, 2014b).

A number of studies have also highlighted some of the safety concerns regarding the use of AVs. Rezaei and Caulfield (2020), Nikitas et al. (2019), Qu et al. (2019), and Noy et al. (2018) pointed to the safety problems of AVs related to the software, control, and operational failures due to the mixture of AVs and human-driven vehicles. Equipment failure was found to be one of the most significant concerns of adopting AVs in the studies conducted by Bansal et al. (2016), Underwood (2014), and Schoettle and Sivak (2014a, 2014b, 2014c). Continental (2015), Kyriakidis et al. (2015), and Howard and Dai (2014) pointed to the safety problem of AVs, such as getting hacked and losing control of the vehicle. Rakotonirainy, Schroeter, and Soro (2014) indicated that AVs may have an obscure understanding of their surrounding environment and may not differentiate between humans, animals, and other objects. Therefore, AVs may not know how to respond in such situations appropriately. In this regard, Schoettle and Sivak (2014c) added that AVs might not be as good as human drivers when it comes to reacting quickly in the case of sudden exposure to surrounding objects or other cars on the road.

2.3. Research contribution

Overall, the studies reviewed in this section show that safety and the reduction in the number and severity of accidents have been recognised as the first and maybe most crucial aspects of using AVs in the view of potential users and transportation professionals. The previous studies identified some of the concerns regarding the adoption of AVs and their consequences on safety. However, most of the studies to date were focused on assessing the public perception of AVs. There has not been a similar survey to date that evaluates AVs' safety from a professional point of view, or they were small survey studies with few numbers of participants.

This paper investigates the possible impacts of the adoption of AVs on the number and severity of accidents using the results of a survey among 185 transportation professionals. A survey of this study adds to the literature by investigating the relationship between some of the technical concerns of adopting AVs such as 'removing steering wheels from AVs' and its possible impact on the number and severity of accidents. In other words, this paper attempt to address the correlation between the causes and effects of the safety concerns of AVs using transportation professionals' opinions. This snapshot represents transportation engineers and researchers' thinking on the safety benefits and concerns related to AVs with a focus on accidents.

The wider research project from which this paper comes from assessed public perception and acceptance of these vehicles through a national survey in Ireland with 474 participants (Rezaei & Caulfield, 2020). The results of this study addressed people's concerns

regarding the adoption of AVs and their willingness to adopt an AV in their life. Then the study conducted a survey amongst 301 international professionals in related fields to gather their comments and thoughts on the substantial risks and advantages of the application of AVs in highway traffic from a professional point of view. The results of these two surveys found that, despite the many benefits of switching to AVs, security concerns, legal liability, and safety concerns are the most substantial concerns of the professionals and road users with regard to adopting AVs. Additionally, professionals demonstrated that a lot more investigation, research, and technology development required before the adoption of AVs on public roads along with improvement in juridical issues and legal liabilities related to the use of the AVs.

The results of this paper will be beneficial for the researchers in academia and private sector professionals as it will provide them with insights into the potential safety downfalls, which could be further investigated in future research projects.

3. Methods

3.1. Data collection

The survey was designed to assess AVs' overall acceptance among transportation professionals while evaluating the possible impact of the adoption of AVs on safety and accidents. When conducting the survey, a transport professional was defined as someone who works in the area of transportation and examining transport issues was/is the main role they undertake in their employment. A similar approach is used in [Liu et al. \(2020\)](#). This paper only focuses on the questions related to the safety of AVs. Four questions were asked to gain an understanding of the participants' demographic details. [Table 1](#) represents the survey questions related to the safety of AVs and demographic questions with their answer options. Full ethical approval was obtained (from our research institution) to conduct this research.

Regarding data collection methods, [Mirabeau, Mignerat, and Grange \(2013\)](#) explained the advantage of using social media networks such as LinkedIn for the purpose of data collection in survey research. Their study found that the upsides of using social media networks for data collection outweigh the risks. In this regard, LinkedIn was found to be a convenient tool for reaching potential candidates in this study. Therefore, the current study used the LinkedIn social media profiles of transportation groups as the primary source for selecting professionals for inclusion in this survey.

A curation process was applied to the collected responses to ascertain that they were valid for evaluation, which its phases are demonstrated in [Table 2](#). In total, 301 responses were collected through the online survey platform of Survey Monkey in 2019. The responses were first checked for completeness and the participants who have completed the entire survey were separated. Those who had a complete set of responses were checked in terms of the participants' background. Those with expertise related to transportation science, including transport engineering, modelling, planning, environment, policy, economics, and psychology were considered for evaluation. Of the total 301 responses collected in this survey, 185 met the criterion considered for inclusion.

The original sample had 13 authority responses, these have been removed from the text as they were deemed not to add to the discussion and narrative to a paper that relies on statistical analysis. In order to avoid unequal sample sizes, which can result in unequal variances between samples, general loss of power, and issues with confounding variables, the focus groups went through an equalisation procedure ([Statisticshowto, 2021](#)). For this purpose, the number of participants within each study group has been checked to ensure the groups have an [almost] equal sample size to be comparable.

Table 1
Survey questions (demographics and safety-related questions).

Question	Answer Options
Segment of the profession	a) Academia, b) Private sector, c) Government, d) Road authority
Experience in the field	a) Below ten years, b) 10–20 years, c) above 20 years
Area of expertise	a) Transportation (Engineering/ Planning /Modelling /Policy /Economics /etc.), b) Civil Engineering, c) Electronic Engineering, d) Mechanical Engineering, e) Computer Engineering, f) Behavioural and Social Sciences, g) Other
Country of residence	A list of all countries in the world
The impact of AVs on the number of accidents	a) Substantially decrease, b) Moderately decrease, c) No impact, d) Moderately increase, e) Substantially increase
The impact of AVs on the severity of accidents	a) Substantially decrease, b) Moderately decrease, c) No impact, d) Moderately increase, e) Substantially increase
Safety is the most valuable outcome of the adoption of AVs	a) Yes, b) No
Safety is the most significant concern regarding the application of AVs	a) Yes, b) No
The most concerning technical issues with an AVs	a) Incorrect understanding of the surrounding objects such as humans and animals, b) Sensor failures and system shut down, c) Not being as good as human drivers in quick driving reactions, d) Getting limited by the factory-defined driving operations such as speeding up/down or queueing
If the emergence of AVs was inevitable, which type of the following AVs would you support?	a) An AV with steering wheel and some manual control systems, b) A Fully Autonomous AV without a steering wheel, c) None
Overall opinion regarding the future use of AVs on the public roads	a) A lot more investigations and preparation needed before AVs' adoption on public roads, b) I am concerned about safety, security and hacking threats but I'd like to try AVs, c) The science and industry of the AVs are doing very well; so, I have no concern to adopt AVs, d) I am opposed to AVs ever being allowed on public roads in any condition, e) Others

Table 2
Sample data curation.

Phase	Action	Description	Sample Size
1	Data collection	Total number of participants before cleaning	301
2	Checking for expertise and survey completeness	Criteria: Selecting participants who completed the survey and had expertise in Transportation *Result: 185 participants met the criteria	185
3	Sector classification	Criteria: Classifying participants based on their segment of the profession Result: number of participants from Academia: 77, Private sector: 108	185
4	Final check	Collection of a sample that participants have: - expertise in Transportation* - completed the survey and answered all questions	185

* Engineering, modelling, planning, environment, policy, economics, psychology.

3.2. Demographics of the sample

Table 3 is a summary of the socio-demographic characteristics of the sample of this study. From this data, it can be seen that 41.6% of the participants in the survey were from academia and 58.4% were from private sector. This demonstrates a fair balance of participants from these two segments of the profession. It can also be observed from Table 3 that 25.4% and 31.4% of the sample had above 10 and 20 years of experience, respectively. This helped ensure that the greater percentage of the sample had more than ten years of experience. This meant that the response would be reliable enough in terms of the aspect of their accuracy and the mixture of various professional points of view regarding the importance of safety and the possible impact of the adoption of AVs on that. However, it is potentially concerning that 43.2% of the participants had under ten years of experience. This is a valid concern in such survey studies. However, it is worth highlighting that this survey's topic is very much related to the possible impact of adopting an emerging technology on safety. For this reason, it was assumed that younger professionals might be more interested in this topic, and therefore they may be well-informed about the technologies involved. This made them a precious asset in this sample.

All participants were from a transportation background, and some had over eight years of experience in the field. This still represents a reasonably high level of experience in the field, but they are included in the group of '1–10 years of experience'. Therefore, the study decided to include the participants of this group in the study sample in order to one) collect responses from a range in experience and perspectives regarding the possible adoption-related impacts of the emerging technologies on safety and two) Evaluating whether experience in the field is an effective parameter related to the participants' response.

Moreover, the demographics illustrate that bar far, the highest number of participants were from Europe at 63.2%. Then, there were professionals from North America and Asia at 14.6% and 13.0%, respectively. Other professionals who participated in this survey were from Oceania, South America, and Africa.

3.3. Analytical approach

The statistical assessments of the professionals survey were conducted using the statistical software IBM SPSS Statistics 25. The cross-tabulation tool of SPSS was used to explain the relationships between the pairs of variables and their sub-groups (answer options). Pearson's Chi-squared test was used as the main quantifier to assess the correlation between the variables and ensure that the results and discussions are statistically significant. A P-value of below 0.05 recognises the statistical significance of the variables involved in the cross-tabulation models. Additionally, Stepwise Linear Regression (SLR) was used to evaluate the importance of

Table 3
Characteristics of the survey sample.

Characteristic	%	n
Segment of profession		
Academia	41.6%	77
Private sector	58.4%	108
Total	100.0%	185
Experience in the field		
1–10 years	43.2%	80
10–20 years	25.4%	47
Above 20 years	31.4%	58
Total	100.0%	185
Continent of residence		
Europe	63.2%	117
North America	14.6%	27
Asia	13.0%	24
Other	9.2%	17
Total	100.0%	185

independent variables over each other where there was a linear correlation between independent and dependant variables. Also, Multinomial Logistic Regression (MNL) model was employed to evaluate the simultaneous impact of a number of variables on professionals' overall opinion about the application of AVs (El-Habil, 2012). The MNL model of this study used the variables with statistical significance, identified from the SLR model, and correlated them with professionals' area of expertise, years of experience, and their perception about the safe operation of AVs with or without a steering wheel.

It is worth highlighting that one of the survey questions was designed with check-box answer option to allow the participants to select multiple responses where they deemed it necessary. This question was the 'technical concerns related to adopting AVs' with four check-box answer options. For this question, the answer options had to be defined independently in SPSS and merged again into one variable. This, however, may have added some bias to the evaluation or slightly skewed the results, but this was unavoidable. Otherwise, each of the answer options should have been assessed individually. In that case, the results could have been more skewed because of ignoring the relationship between each of the answer options and the rest, aside from adding more time and calculations to the assessment. For this reason, in the evaluations associated with this question, the Pearson Chi-squared test was conducted on all the individual answer options as independent variables and on the merged variables to consider the impact of the variable transformation. This question will be analysed with more caution as a result.

This paper's contents explain some of the main concerns of transportation professionals regarding the adoption and associated impact of AVs on safety and the participants' overall opinion on whether AVs would be safe enough to be adopted in the road based transport environment or whether more preparation is yet required. In order to perform this assessment, the safety analysis was broken down into smaller steps. For this, the current paper evaluates the various parameters that are speculated to impact safety, or that may result in a safety concern. As such, some of the technical concerns of adopting AVs were also evaluated like the concern that 'AVs may not be as good as human drivers in reacting quickly and properly when required'. AVs may have an impact on accidents by increasing or decreasing the number or severity of accidents. Therefore this paper investigates the parameters that may result in a safety benefit or risk such as accidents. However, some of the parameters may not affect safety, which will be identified throughout this paper's analysis. Finally, the study shows how the parameters with possible safety-related outcomes may have impacted the overall opinion of the survey sample regarding AVs' adoption. The content of the paper explains the relationships present between the impacts of adopting AVs and:

- Safety and technical concerns
- Technical concerns and the number and severity of accidents
- Accidents and the overall opinion of whether AVs are safe enough to be adopted on public roads or not.
- An analysis of the professionals' overall opinion about the application of AVs their potential underlying reasons

4. Results

4.1. Test Statistics

As previously explained in the methodology section, Pearson's Chi-squared test was conducted to ensure that the survey sample's responses are statistically significant and valid for evaluation. Table 4 shows the results of this test.

Looking at Table 4, the survey question about whether 'Safe driving would be the most valuable outcome of adopting AVs' shows a *P-value* of 0.000. This is much lower than the required model acceptance criteria of 0.05. Therefore, the responses collected for this question are statistically significant. The results of the statistical assessment for each of the survey variables and their collected responses can be seen in Table 4.

In the next step, the Pearson test was used to measure the statistical significance of the correlation between the safety variables and AVs' adoption impacts. For this, the study crosschecked a number of the survey questions together (also called test pairs) in which they

Table 4
Test statistics.

Variable (survey question)	χ^2^*	Df ^{**}	P-value
Safe driving would be the most valuable outcome of adopting AVs	16.351	1	0.000
Impact of adopting AVs on Safety	29.027	4	0.000
Impact of adopting AVs on the Number of Accidents	62.919	4	0.000
Impact of adopting AVs on the Severity of Accidents	58.162	4	0.000
Safety would be the most significant concern of adopting AVs	1.216	1	0.270
Sensor Failure would be the most significant technical concern	0.265	1	0.607
Incorrect understanding would be the most significant technical concern	32.049	1	0.000
Restricted driving behaviour would be the most significant technical concern	104.438	1	0.000
Not being as good as human drivers would be the most significant technical concern	89.951	1	0.000
Overall opinion regarding the application of AVs	184.432	4	0.000
Type of AVs (with/out steering wheel)	76.746	2	0.000
Years of Experience	9.157	2	0.010
Occupation	5.195	1	0.023

* Chi-Square value.

** Degrees of freedom.

were speculated to have a meaningful correlation with safety such as the test pairs of ‘technical concerns’ and ‘the number of accidents’. Table 5 demonstrates a list of the cross-tabulation test pairs evaluated in this regard with their Pearson test results.

Table 5 demonstrates that five test pairs show a P-value below 0.05 which demonstrates that the correlation between these pairs’ variables is statistically significant. Therefore the pairs will be further evaluated in the next steps. However, the rest of the cross-tabulation test pairs showed P-values of above 0.05, which means that a valid correlation between the test pairs’ parameters cannot be statistically proved. However, as explained in the methodology of this paper, each of the answer options related to the question ‘technical concerns of adopting AVs’ were defined individually in SPSS and merged again to be used for the cross-tabulation. For this, the cross-tabulation of ‘technical concerns’ with ‘number of accidents’ and ‘severity of accidents’ showed an overall significance of 0.68 while three of the answer options related to the technical concerns showed a significance of 0.000. The study took these two cross-tabulation pairs (Pairs no. 7 and 8 in Table 5) into a further evaluation stage while accepting the small deviation in the overall results related to them.

According to the results in Table 5, no valid correlation was seen between the participants’ years of experience and their overall opinion about whether the AVs would be safe and secure enough to be adopted in the road network environment or not. This, however, does not ignore the impact of the participants’ experience and their level of expertise on their responses, but do indicate that participants’ opinion about finding AVs to be safe was impacted by other parameters such as the ‘number of accidents’ that showed a P-value of 0.007 (pair no. 2). In the same way, the participants’ occupation – whether they were working in private sector or academia – did not prove to be impactful on the participants’ overall opinions. This could be for several reasons, of which *the topic of AVs being well-placed and favoured in both occupations* could be one of them. This means that there seems to be no significant difference between the professionals’ opinions of these two occupancies regarding the impact of AVs on safety, and they may even have opinions that are in line with each other. This also validates the fair balance of the sample in this regard. Also available in Table 5, some other test pairs showed a Pearson P-values of above 0.05; therefore, a significant correlation between their associated variables cannot be proved.

In the next sections, the paper will focus on addressing the relationships between the test pairs in Table 5 in which a significant correlation between their associated variables has been identified along with the test pairs of ‘technical concerns’ with the ‘number of accidents’ and ‘severity of accidents’.

4.2. Safety and technical concerns

The participants of the survey were asked which type of AV they would consider being safer and would therefore recommend being adopted for the road network: ‘an AV with a steering wheel and manual override control systems’ which allowed the driver to take over control of the vehicle at any time and in any condition or ‘an AV without a steering wheel’ which is a fully driverless AV that conducts all driving operations by itself. It should be noted that according to SAE and NHTSA (2019), both level 4 and level 5 AVs might be equipped with a steering wheel and manual control operations, and therefore fully autonomous driving does not necessarily relate to the presence or absence of a steering wheel. However, these questions aimed to address the level of concern linked to AV adoption by removing the steering wheel from them. However, an investigation into the Tesla vehicle crash in 2018 indicates that keeping steering wheels in AVs and taking over the control of the vehicle (which is also called disengagement) may not be a viable action in some situations, such as after an extensive period of inattention (NTSB, 2018). Failing to appropriately take over the AV’s control might make it less safe if the AVs have a steering wheel. This is a valid concern, but it requires more investigation since AVs are not fully operating on public roads, and many of their behaviours are unknown. Therefore the analysis in this section will help to understand if there is any relationship between having a steering wheel or removing it from the vehicle and concern about the safety of the AVs. The question related to keeping or removing the steering wheel is correlated with the question ‘safety would be a significant concern of adopting AVs’ with the response options of ‘Yes’ and ‘No’. The analysis results demonstrate the impact of adopting AVs with or without a steering wheel on safety concerns. Table 6 illustrates the cross-tabulation of this assessment.

Looking at Table 6, 54.1% of the total respondents (185) believed that safety is not a substantial concern regarding AVs’ application, with more than half of them declaring that they would recommend an AV without a steering wheel. This is proven by the result

Table 5
Statistics of the cross-tabulation test pairs.

Pair No.	Cross-tabulation test pairs	Pearson Test Results		
		χ^2 *	Df*	P-value
1	‘Technical concerns of adopting AVs’ versus ‘safety being the most significant concern of adopting AVs’	28.70	4	0.000
2	‘The adoption impact of AVs on the number of accidents’ versus ‘overall opinion’	33.06	16	0.007
3	‘Technical concerns about adopting AVs’ versus ‘overall opinion’	33.40	16	0.007
4	‘Safety being the most significant concern’ versus ‘AVs not/having steering wheel’	7.69	2	0.021
5	‘The adoption impact of AVs on the severity of accidents’ versus ‘overall opinion’	29.39	16	0.021
6	‘Participants’ years of experience’ versus their ‘overall opinion’	15.12	08	0.057
7	‘Technical concerns about adopting AVs’ versus ‘the number of accidents’	25.18	16	0.068
8	‘Technical concerns about adopting AVs’ versus ‘the severity of accidents’	25.09	16	0.068
9	‘The adoption impact of AVs on road safety’ versus ‘overall opinion’	24.18	16	0.086
10	‘participants’ occupancy’ versus their ‘overall opinion’	7.42	4	0.115

* Chi-Square value.

** Degrees of freedom.

showing that 65.1% of the respondents who recommended AVs without a steering wheel believed that safety is not a significant concern when adopting AVs. Based on the results shown in Table 6, 61.2% of the participants who believed that safety is a significant concern, and 51.9% of the total participants recommended AVs with a steering wheel. From another point of view, 34.9% of the professionals who recommended AVs without a steering wheel they believed that safety is a significant concern of adopting AVs, which can indicate that keeping steering wheels may also increase safety concerns too; however, this requires more investigation. Overall, the results in this section prove that there is a significant correlation between safety concerns and removing the steering wheel from AVs. The accuracy of the results in this section has been proved by the Pearson *P*-value of 0.021.

In another investigation, some of the technical concerns related to adopting AVs were correlated with safety being a significant concern. The results are shown in Table 7. As previously explained in the methods section, the question related to AVs' technical concerns allowed the participants to select multiple responses. Overall, 278 responses were recorded; 47.1% of them recognised the AVs incorrect understanding of the surrounding objects as the most significant technical concern. Safety was also considered to be a significant concern, according to 54.7% of the total responses. The results overall verify the presence of a valid correlation between safety and technical concern.

Upon addressing the relationship between technical concerns and safety, the study has also conducted further assessments to capture how technical concerns can impact the overall opinions regarding AVs' use. The results are shown in Table 8. An incorrect understanding of the surrounding environment by the AV was selected by 47.1% out of the total of 278 responses recorded for this evaluation (multiple responses were allowed). Almost half of the 47.1% of responses demonstrated that more Research and Development (R & D) is required before adopting AVs on public roads. Also, 57.2% of the total (278) responses collected in this assessment agreed that more R&D is required. Besides, other responses were recorded for the question asking about the participants' overall opinion of the adoption of AVs among which 'safety concerns', 'legal liability', 'establishing regulatory frameworks about testing and operation of AVs', and the 'trust of the AV users to hand over the entire driving operation to machines' were the most repeated comments. The accuracy of the results in this evaluation was proved by the *P*-value of 0.007. This indicates that the correlation between technical concerns and overall opinions is statistically significant.

4.3. Technical concerns and accidents

In section 4.2., the paper addressed the relationship between the safe operation of AVs and some of the technical concerns of adopting these vehicles. This section aims to address the relationship between these technical concerns and the number and severity of accidents. Tables 9 and 10 represent the results of these evaluations.

As previously identified in the results related to the technical concerns of adopting AVs, and according to the results demonstrated in Tables 9, 'incorrect understanding of the surrounding objects such as humans, animals and static objects' was recognised as the most substantial technical concern as it made up 47.1% of the total (278) responses collected for this evaluation. In addition, other technical concerns such as 'sensor failures and system shutdown', 'not being as good as human drivers in performing well and quick in unexpected driving operations', and 'restricted driving operations of AVs' were considered to be the next significant technical concerns related to adopting AVs by 34.5%, 10.1%, and 8.3% of the total (of 278) responses collected for this evaluation respectively. However, of the 47.1% responses that selected 'incorrect understating' as the main technical concern, about 37.4% and 31.3% of them indicated that through AVs' adoption, the number of accidents would substantially and moderately decrease respectively. This statement is also supported by (the sum of 31.3% and 33.5%) 64.8% of the responses. Only 19.8% (the sum of 12.6% and 7.2%) of the total responses pointed to an increase in the number of accidents resulting from the adoption of AVs. Also, 15.5% indicated that AVs would have no impact on the number of accidents.

Table 10 also represents the results of the investigation into the relationship between the technical concerns and the severity of accidents. Looking at Table 10, the results follow an almost a similar pattern to what has been demonstrated in Table 9 but with a subtle variation. The results show that the severity of accidents may not substantially decrease by adopting AVs, although it may vary

Table 6

The relationship between the presence of a steering wheel and safety.

		AVs with a steering wheel	AVs without a steering wheel	None	Total
Safety 'is not' a significant concern of adopting AVs	Count	44	54	2	100
	% within Safety	44.0%	54.0%	2.0%	100.0%
	% within Type of AV	45.8%	65.1%	33.3%	54.1%
Safety 'is' a significant concern of adopting AVs	Count	52	29	4	85
	% within Safety	61.2%	34.1%	4.7%	100.0%
	% within Type of AV	54.2%	34.9%	66.7%	45.9%
Total	Count	96	83	6	185
	% within Safety	51.9%	44.9%	3.2%	100.0%
	% within Type of AV	100.0%	100.0%	100.0%	100.0%

χ^2 : 7.69, Degrees of freedom: 2, *P*-value: 0.021.

Table 7

The relationship between technical concerns and safety.

Most Significant Technical Concern		Safety is a significant concern of adopting AVs		
		No	Yes	Total
Sensor Failure (SF) [*]	Count	40	56	96
	% within SF	31.7%	36.8%	34.5%
	% within Safety	41.7%	58.3%	100.0%
Incorrect Understanding (IU) ^{**}	Count	71	60	131
	% within IU	56.3%	39.5%	47.1%
	% within Safety	54.2%	45.8%	100.0%
Getting Limited (GL) ^{***}	Count	9	14	23
	% within GL	7.1%	9.2%	8.3%
	% within Safety	39.1%	60.9%	100.0%
Not as Good as Human (NGH) ^{****}	Count	6	22	28
	% within NGH	4.8%	14.5%	10.1%
	% within Safety	21.4%	78.6%	100.0%
Total	Count	126	152	278
	% within Technical Concern	100.0%	100.0%	100.0%
	% within Safety	45.3%	54.7%	100.0%

^{*} χ^2 : 0.265, Degrees of freedom = 1, P-value = 0.607.^{**} χ^2 : 32.04, Degrees of freedom = 1, P-value = 0.000.^{***} χ^2 : 104.43, Degrees of freedom = 1, P-value = 0.000.^{****} χ^2 : 89.95, Degrees of freedom = 1, P-value = 0.000.**Table 8**

The relationship between the 'technical concerns' and 'overall opinions'

Response		No concern to adopt AVs ¹	Concerned but Interested to try AVs ²	More R&D required ³	Totally against AVs ⁴	Others	Total
Sensor Failure (SF)	Count	6	25	60	2	3	96
	% within SF	6.3%	26.0%	62.5%	2.1%	3.1%	100.0%
	% within opinion	30.0%	32.1%	37.7%	40.0%	18.8%	34.5%
Incorrect Understanding (IU)	Count	14	36	69	1	11	131
	% within IU	10.7%	27.5%	52.7%	0.8%	8.4%	100.0%
	% within opinion	70.0%	46.2%	43.4%	20.0%	68.8%	47.1%
Getting Limited (GL)	Count	0	5	16	1	1	23
	% within GL	0.0%	21.7%	69.6%	4.3%	4.3%	100.0%
	% within opinion	0.0%	6.4%	10.1%	20.0%	6.3%	8.3%
Not as Good as Human (NGH)	Count	0	12	14	1	1	28
	% within NGH	0.0%	42.9%	50.0%	3.6%	3.6%	100.0%
	% within opinion	0.0%	15.4%	8.8%	20.0%	6.3%	10.1%
Total	Count	20	78	159	5	16	278
	% within technical concern	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	% within opinion	7.2%	28.1%	57.2%	1.8%	5.8%	100.0%

 χ^2 : 33.40, Degrees of freedom: 16, P-value: 0.007.¹ The science and industry of the AVs are doing very well; so, I have no concern to adopt AVs.² I am concerned about safety, but I would like to try AVs.³ A lot more investigations and preparation needed before AVs' adoption on public roads.⁴ I am opposed to AVs ever being allowed on public roads in any condition.

between a moderate change to no impact at all. Therefore, AVs' adoption may have more impact on the number of accidents rather than reducing the severity of them. From another perspective, 8.6% and 6.5% of the total responses pointed that through AVs' adoption, the severity of accidents will moderately and substantially increase, respectively. This indicates that there is a chance that AVs reduce the number of accidents but increase the severity of them, which requires further investigation.

Table 9

Technical concerns and the number of accidents.

Most significant technical concerns of adopting AVs		Number of Accidents					Total
		Substantially decrease ³	Moderately decrease	No impact	Moderately increase	Substantially increase	
Sensor Failure[*]	Count	31	29	15	12	9	96
	% within NoA ^a	35.6%	31.2%	34.9%	34.3%	45.0%	34.5%
	% within TC ^b	32.3%	30.2%	15.6%	12.5%	9.4%	100.0%
Incorrect Understanding^{**}	Count	49	41	17	14	10	131
	% within NoA ^a	56.3%	44.1%	39.5%	40.0%	50.0%	47.1%
	% within TC ^b	37.4%	31.3%	13.0%	10.7%	7.6%	100.0%
Getting Limited^{***}	Count	2	12	5	4	0	23
	% within NoA ^a	2.3%	12.9%	11.6%	11.4%	0.0%	8.3%
	% within TC ^b	4.3%	26.1%	10.9%	8.7%	0.0%	100.0%
Not as Good as Humans^{****}	Count	5	11	6	5	1	28
	% within NoA ^a	5.7%	11.8%	14.0%	14.3%	5.0%	10.1%
	% within TC ^b	17.9%	39.3%	21.4%	17.9%	3.6%	100.0%
Total	Count	87	93	43	35	20	278
	% within NoA ^a	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	% within TC ^b	31.3%	33.5%	15.5%	12.6%	7.2%	100.0%

* χ^2 : 0.265, Degrees of freedom: 1, P-value: 0.607.** χ^2 : 32.04, Degrees of freedom: 1, P-value: 0.000.*** χ^2 : 104.43, Degrees of freedom: 1, P-value: 0.000.**** χ^2 : 89.95, Degrees of freedom: 1, P-value: 0.000.^a Number of Accidents^b Technical Concern

4.4. Accidents and overall opinion

So far in this paper, the impact of some of the technical concerns related to the adoption of AVs on accidents and safety have been addressed. It would be useful to identify whether the AVs' potential to affect the number and severity of accidents could majorly impact the overall opinions regarding the adoption of AVs on public roads or not. This section evaluates such possibilities through the cross-tabulation of the overall opinions on the application of AVs and the intensity of the effect that they may have on the number and severity of road accidents. Tables 11 and 12 demonstrate the results of these evaluations.

Based on the results in Table 11, 34.6% and 33.5% of the survey sample believed that AVs' introduction would substantially and moderately decrease the number of accidents, respectively. Besides, 57.3% of the total participants also believed that more research is required. This is also proven by the results where 57.3% of the participants pointed out the need for more R&D while 36.8% and 34.9% of them also pointed to a substantial and moderate decrease respectively in the number of accidents by the introduction of AVs to public road transport. Moreover, 14.1% of the total participants stated that AVs would have a neutral impact on accidents. They also believed that more R&D is required. These results also seem to be in line with the results on the relationship between the overall opinions of the sample and the severity of accidents, represented in Table 12. However, looking at Table 12, a slightly higher percentage of the total participants, 22.7%, believe that AVs will have no impact on the severity of accidents while still believing that more R&D is required. This percentage was 14.1% for the number of accidents (represented in Table 11). The accuracy of the results is proven by the *P-values* of 0.007 and 0.021 for the number of accidents and the severity of accidents, respectively. This demonstrates that the correlations between the associated parameters in the test pairs are statistically significant.

4.5. What lies behind the overall opinion

The study adopted a backward regression model to identify how professionals' occupation, years of experience, and their opinion about AVs steering wheel impacted their overall opinions about the application of these vehicles. In this regard, professionals' 'experience', 'occupation' and opinion about 'type of AVs' were defined as independent variables for the model in the first step and

Table 10

Technical concern and the severity of accidents.

Most Significant Technical Concern		Severity of Accidents					Total
		Substantially decrease	Moderately decrease	No impact	Moderately increase	Substantially increase	
Sensor Failure[*]	Count	21	36	23	7	9	96
	% within SoA ^a	32.8%	37.1%	30.7%	29.2%	50.0%	34.5%
	% within TC ^b	21.9%	37.5%	24.0%	7.3%	9.4%	100.0%
Incorrect Understanding^{**}	Count	34	43	34	11	9	131
	% within SoA ^a	53.1%	44.3%	45.3%	45.8%	50.0%	47.1%
	% within TC ^b	26.0%	32.8%	26.0%	8.4%	6.9%	100.0%
Getting Limited^{***}	Count	2	11	9	1	0	23
	% within SoA ^a	3.1%	11.3%	12.0%	4.2%	0.0%	8.3%
	% within TC ^b	8.7%	47.8%	39.1%	4.3%	0.0%	100.0%
Not as Good as Humans^{****}	Count	7	7	9	5	0	28
	% within SoA ^a	10.9%	7.2%	12.0%	20.8%	0.0%	10.1%
	% within TC ^b	25.0%	25.0%	32.1%	17.9%	0.0%	100.0%
Total	Count	64	97	75	24	18	278
	% within SoA ^a	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	% within TC ^b	23.0%	34.9%	27.0%	8.6%	6.5%	100.0%

* χ^2 : 0.265, Degrees of freedom: 1, P-value: 0.607.** χ^2 : 32.04, Degrees of freedom: 1, P-value: 0.000.*** χ^2 : 104.43, Degrees of freedom: 1, P-value: 0.000.**** χ^2 = 89.95, Degrees of freedom: 1, P-value: 0.000.^a Severity of Accidents.^b Technical Concern.

correlate with the responses related to overall opinions about the application of AVs. Then the backward regression model evaluated the probability of the f-test to remove the independent variables (F -to-remove ≤ 0.1000) whose loss [the most insignificantly] deteriorates the model fit. In other words, the model removes the variable that does not correlate with the dependant variable of the model and will leave the model with the independent variable with the most statistical significance on the model result. This process will be repeated until no more variable is deleted without a statistically significant loss of fit. This method is previously used by [Rezaei and Caulfield \(2020\)](#), and [Stefansdottir, Næss, and Ihlebæk \(2019\)](#). The dependent and independent variables of the backward regression model are as follows:

Dependent Variable:

- Overall opinion regarding the application of AVs

Independent Variables:

- Years of Experience
- Occupation
- Type of AVs (with or without steering wheel)

The model summary of the assessment, shown in [Table 13](#), represents p values of 0.000 for both steps of the model, which are less than 0.05, verifying the goodness of fit. Also, shown in [Table 14](#), model coefficients provide insights into which independent variable had more impact on professionals' overall opinion about the application of AVs. According to [Table 14](#), the independent variable 'Occupation' had a p-value of 0.802 in step one of the model, which is greater than 0.1 (parameter removal criteria). It means that 'Occupation' had the greatest degradation of the model fit in step one; therefore, it is removed from the model. The rest of the variables 'Years of Experience' and 'Type of AVs' entered the next step for another round of correlation. In step two, variables 'Years of Experience' and 'Type of AVs' show p-values of 0.001 and 0.004, respectively; both below the parameter removal criteria. This means

Table 11

The impact of adopting AVs on the ‘number of accidents’ and ‘Overall Opinion’

Overall Opinion		Impact on the Number of Accidents					
		Substantially decrease	Moderately decrease	No impact	Moderately increase	Substantially increase	Total
No concern to adopt AVs	Count	10	5	0	0	3	18
	% within OO ^a	55.6%	27.8%	0.0%	0.0%	16.7%	100.0%
	% within NoA ^b	15.6%	8.1%	0.0%	0.0%	21.4%	9.7%
Concerned but want to try AVs	Count	10	14	8	8	3	43
	% within OO ^a	23.3%	32.6%	18.6%	18.6%	7.0%	100.0%
	% within NoA ^b	15.6%	22.6%	30.8%	42.1%	21.4%	23.2%
More R&D required	Count	39	37	16	9	5	106
	% within OO ^a	36.8%	34.9%	15.1%	8.5%	4.7%	100.0%
	% within NoA ^b	60.9%	59.7%	61.5%	47.4%	35.7%	57.3%
Totally against AVs	Count	0	0	2	0	0	2
	% within OO ^a	0.0%	0.0%	100.0%	0.0%	0.0%	100.0%
	% within NoA ^b	0.0%	0.0%	7.7%	0.0%	0.0%	1.1%
Others	Count	5	6	0	2	3	16
	% within OO ^a	31.3%	37.5%	0.0%	12.5%	18.8%	100.0%
	% within NoA ^b	7.8%	9.7%	0.0%	10.5%	21.4%	8.6%
Total	Count	64	62	26	19	14	185
	% within OO ^a	34.6%	33.5%	14.1%	10.3%	7.6%	100.0%
	% within NoA ^b	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

X²: 33.06, Degrees of freedom: 16, P-value: 0.007.^a Overall Opinion.^b Number of Accidents.

that there are no other variables to make a statistically significant loss of fit to the model. Hence, both ‘Years of Experience’ and ‘Type of AVs’ impact professionals’ opinion about the application of AVs. Out of these two variables, the one with the greatest β -coefficient would represent the variable with the greatest impact on professionals’ opinions in this assessment. In this context, ‘Type of AVs’ with the β -coefficient of 0.347 is the variable that most substantially impacts professionals’ opinions on the application of AVs, then the professionals’ ‘Years of Experience’ with the β -coefficient of 0.259.

Despite that the SLR model showed high statistical significance on correlations between [the independent parameters of] professionals’ experience and type of AVs they considered safe on [the dependent parameter] overall opinions about the application of AVs, the study deemed necessary to investigate further the simultaneous impact of those independent parameters on the professionals’ overall opinion. In this regard, the study put the model variables into an MNL model.

Table 15 represents the results of the MNL model. The model fitting test presented a p-value of 0.00 that is below 0.05, meaning that the model results are statistically significant. The model also got a Pseudo R-squared value of 0.256 in the Nagelkerke test, showing the correlation between the model’s predicted values and the actual values.

The results of the MNL model shows that professionals with 10–20 years of experience were 2.32 times ($\text{Exp}(\beta) = 2.323$) more likely to be concerned but interested in trying AVs than the professionals with above 20 years of experience. The positive β Coefficient of 0.843 approves such a statement. Those professionals interested in trying AVs were also 5.79 times ($\text{Exp}(\beta) = 6.455/1.114$) more likely to believe in the safe operation of AVs without steering wheel than those professionals who believed AVs should have a steering wheel. The observation also shows that professionals from academia were 0.79 times more likely ($\text{Exp}(\beta) = 0.791$) to be concerned but interested in driving AVs than the industry professionals’.

The MNL model results related to the professionals’ who believed in the need for more research and development (R&D) before adopting AVs on public roads showed almost similar results as to the assessment related to those interested in trying AVs. Professionals with 10–20 years of experience were more likely to believe in the safe operation of AVs without a steering wheel, yet believing more R&D would be required than those professionals with above 20 years of experience.

Table 12

The impact of adopting AVs on the ‘severity of accidents’ and ‘Overall Opinion’

Overall Opinion		Impact on the Severity of Accidents					
		Substantially decrease	Moderately decrease	No impact	Moderately increase	Substantially increase	Total
No concern to adopt AVs	Count	9	4	2	0	3	18
	% within OO ^a	50.0%	22.2%	11.1%	0.0%	16.7%	100.0%
	% within SoA ^b	19.1%	5.9%	4.8%	0.0%	25.0%	9.7%
Concerned but want to try AVs	Count	6	15	12	6	4	43
	% within OO ^a	14.0%	34.9%	27.9%	14.0%	9.3%	100.0%
	% within SoA ^b	12.8%	22.1%	28.6%	37.5%	33.3%	23.2%
More R&D required	Count	29	43	24	7	3	106
	% within OO ^a	27.4%	40.6%	22.6%	6.6%	2.8%	100.0%
	% within SoA ^b	61.7%	63.2%	57.1%	43.8%	25.0%	57.3%
Totally against AVs	Count	0	0	2	0	0	2
	% within OO ^a	0.0%	0.0%	100.0%	0.0%	0.0%	100.0%
	% within SoA ^b	0.0%	0.0%	4.8%	0.0%	0.0%	1.1%
Others	Count	3	6	2	3	2	16
	% within OO ^a	18.8%	37.5%	12.5%	18.8%	12.5%	100.0%
	% within SoA ^b	6.4%	8.8%	4.8%	18.8%	16.7%	8.6%
Total	Count	47	68	42	16	12	185
	% within OO ^a	25.4%	36.8%	22.7%	8.6%	6.5%	100.0%
	% within SoA ^b	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

X²: 29.39, Degrees of freedom: 16, P-value: 0.021.^a Overall Opinion.^b Severity of Accidents.**Table 13**

Model summary of the backward regression.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.321	0.103	0.088	0.918
2	0.320	0.103	0.093	0.916

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	17.495	3	5.832	6.919	0.000
	Residual	152.559	181	0.843		
	Total	170.054	184			
2	Regression	17.442	2	8.721	10.400	0.000
	Residual	152.612	182	0.839		
	Total	170.054	184			

5. Discussion

This study's investigation revealed a significant correlation between removing steering wheels from AVs and safety concerns. In this regard, when AVs without a steering wheel were recommended, no significant concern was seen about their adoption. However, when safety was found to be a significant concern related to adopting AVs, a steering wheel was also recommended to be kept in the vehicle because it was believed that keeping the steering wheel may increase the chance of the human driver engaging in time and taking control of the AV where it is deemed necessary. This also states that human drivers are better than machines in reacting quickly

Table 14

Model results of the backward regression.

Step	Variable	Unstandardised β	Std. Error	Standardised Coefficients β	t	Sig.
1	(Constant)	1.794	0.309		5.798	0.000
	Years of Experience	0.264	0.081	0.236	3.244	0.001
	Occupation	−0.035	0.141	−0.018	−0.252	0.802
	Type of AVs	0.345	0.121	0.202	2.852	0.005
2	(Constant)	1.743	0.235		7.409	0.000
	Years of Experience	0.259	0.079	0.231	3.285	0.001
	Type of AVs	0.347	0.120	0.203	2.884	0.004

Table 15

Results of the MNL model.

Variable ^a	Model Coefficient: β	Odds Ratio: Exp (β)	Sig.
I am concerned about safety, security, and hacking threats, but I would like to try AVs			
1–10 Years Experience	0.250	1.284	0.737
10–20 Years Experience	0.843	2.323	0.351
Above 20 Years Experience	0.000 ^b		
AV With Steering Wheel	−16.010	1.114	0.000
AV Without Steering Wheel	−16.556	6.455	0.000
None	0.000 ^b		
Academia	−0.234	0.791	0.699
Industry	0.000 ^b		
A lot more investigations and preparation needed before AVs' adoption on public roads			
1–10 Years Experience	−1.098	0.334	0.091
10–20 Years Experience	−0.108	0.898	0.894
Above 20 Years Experience	0.000 ^b		
AV With Steering Wheel	−15.892	1.254	0.000
AV Without Steering Wheel	−15.763	1.426	0.000
None	0.000 ^b		
Academia	0.671	1.956	0.221
Industry	0.000 ^b		
I am opposed to AVs ever being allowed on public roads in any condition			
1–10 Years Experience	−1.015	0.363	0.610
10–20 Years Experience	−0.170	0.844	0.999
Above 20 Years Experience	0.000 ^b		
AV With Steering Wheel	−28.239	5.442	0.686
AV Without Steering Wheel	−28.189	5.726	0.699
None	0.000 ^b		
Academia	0.147	1.159	0.939
Industry	0.000 ^b		
Others			
1–10 Years Experience	−2.180	0.113	0.032
10–20 Years Experience	0.207	1.231	0.828
Above 20 Years Experience	0.000 ^b		
AV With Steering Wheel	−18.149	1.312	0.000
AV Without Steering Wheel	−16.957	4.323	
None	0.000 ^b		
Academia	−0.553	0.575	0.515
Industry	0.000 ^b		

Chi-Square: 48.395, Degrees of freedom: 20, P-value: 0.000, Pseudo R-square: 0.256, −2 Log Likelihood: 108.605.

^a The reference category is: “The science and industry of the AVs are doing very well. So, I have no concern to adopt AVs.”^b This parameter is set to zero because it is the base category (the reference for comparisons).

to unexpected incidents. Such a result was also found by [Rezaei and Caulfield \(2020\)](#) and [Schoettle and Sivak \(2014c\)](#). Besides, the sample of this study found that ‘incorrect understanding of the surrounding objects by AVs’ would be the most significant technical concern when adopting AVs, which may increase safety concerns. Such a result was also found by [Rezaei and Caulfield \(2020\)](#) and [Schoettle and Sivak \(2014c\)](#), while [Katrakazas et al. \(2015\)](#) disagree with such a statement. [Katrakazas et al. \(2015\)](#) stated that ‘identifying of surrounding objects such as human and animals’ is a safety benefit of adopting AVs. More than half of the sample in this study believe that more research is required to make a better statement in this regard. The level 5 AVs are claimed to be performing much better than human drivers in terms of reacting quickly in the event of unexpected incidents ([Bansal et al., 2016](#); [Howard & Dai, 2014](#); [Vander Laan & Sadabadi, 2017](#); [Papadoulis et al., 2019](#)). [Noy et al. \(2018\)](#), and [Tabitha et al. \(2018\)](#) relate this to smart sensors, which makes the AVs better at avoiding collisions in such situations. The results of a recent study by [Wang and Li \(2019\)](#) also indicate that keeping the steering wheel in AVs will require disengagement from autonomous driving and taking back control from the AV by a

human driver. This may result in a collision like what happened to Tesla's AV, which also had a steering wheel and a human driver (NTSB, 2018). This result proves the statement presented by Fagnant and Kockelman (2015), saying that accidents related to passenger cars are mostly the result of driver errors such as distraction, fatigue, and drowsiness. These are all human errors, and they could all be eliminated by AVs. Wang and Li (2019) recommend that disengagement from automated driving could be reduced by installing more radar sensors. This may help keep the human driver in control of the AV and resolve the safety concern of removing the steering wheel. However, based on the results obtained in this study on the concern of removing steering wheels, based on the results of the studies reviewed in the literature and based on the experience gained from Tesla's AV crash, there is a chance that having a steering wheel may be a disadvantage related to AVs' safety. The results of this study also reflect the concerns of the professionals regarding trusting vehicles without steering wheels and prove the results of the studies by Rezaei and Caulfield (2020) and Schoettle and Sivak (2014c) in this regard.

Regarding the impact of adopting AVs on accidents, the results in this paper showed that the survey sample identified 'incorrect understanding of the surrounding objects' as the most significant technical concern of adopting AVs. The next substantial technical concerns were found to be 'sensor failures and system shutdown', 'not being as good as human drivers in performing well and quick in unexpected driving operations', and 'restricted driving operations of AVs'. Fixing these issues will require more development in the technology of AVs. More than half of the sample of this study indicated that through the adoption of AVs, the number of accidents will decrease between moderately and substantially and only a few of the professionals expressed that there might be an increase in the number of accidents on public roads as a result of the adoption of AVs. This result proves the statement that has already been presented by several other studies such as those by Hulse et al. (2018), Bansal et al. (2016), Katakazas et al. (2015), and Fagnant and Kockelman (2015) saying that accidents related to passenger cars are mostly the result of driver errors and could be eliminated by AVs. Moreover, the results of the current study indicate that AVs can reduce the number and severity of accidents. This validates the results of the previous studies such as those by Hulse et al. (2018), Bansal et al. (2016), Continental (2015), Howard and Dai (2014), Underwood (2014) and Schoettle and Sivak (2014a, 2014c) in this context. However, this paper's results show that AVs might be better at reducing the number of accidents rather than the severity of them. However, studies such as those by Hulse et al. (2018), Howard and Dai (2014), and Underwood (2014) consider an equal potential for there to be a reduction in both the 'number' and 'severity' of accidents by AVs. Continental (2015) and Schoettle and Sivak (2014a, 2014c) found the 'reduction in the severity of accidents' to be a more potential outcome of adopting AVs than the 'reduction in the number of accidents'. This is worth more investigation as it may be considered a double-edged sword of having more accidents with less severity or having fewer accidents with more intensity.

Overall, the results related to the impact of the number and severity of accidents based on the professionals' overall opinion of the adoption of AVs indicate that the majority of the survey sample agreed that AVs have the potential to reduce the number and severity of accidents to a substantial and moderate level respectively. However, over half of the sample also believed that more research and development would be required in this context to ensure that AVs are safe enough to be adopted on public roads. This consolidates the results of the studies conducted by Collingwood (2017), Bansal and Kockelman (2017), Bansal et al. (2016), Kyriakidis et al. (2015), Anderson et al. (2014), and Howard and Dai (2014), indicating that there is still a need for a legal framework for the AVs' safe testing operations. However, Lee and Hess (2020), Costantini et al. (2020), Wang and Li (2019), and Imai (2019) report there to have been a number of advancements in the regulations for data protection and the safe testing and operation of AVs. They also report that AVs' testing phase has already been started in several US states, Europe, Asia, and Australia, which shows that there is some light at the end of the tunnel of AV research and industry.

6. Conclusions

6.1. Main findings

The research conducted in this paper has produced several interesting findings which add to the body of work that has been completed in this field. The results show that over half (51.9%) of the professionals had concerns about trusting the AVs' safe operation without steering wheels, and they believe that keeping the steering wheels in AVs will guarantee the safer operation of the AVs rather than removing them. The results also showed that, 41.9% of the professionals had no significant concerns about AVs' safe operation without steering wheels, or they believed that there is a chance that having steering wheels may increase safety concerns that may also intensify the chance of accidents. Professionals with 10–20 years of experience were more likely to believe in the safe operation of AVs without a steering wheel, yet believing more R&D would be required than those professionals with above 20 years of experience. The incorrect understanding of the surrounding objects such as humans, animals, and static and dynamic objects is the most significant technical concern regarding AVs' safe operation, by 47.1% of the total responses. This may lead to accidents more than any of the other technical issues studied in this paper. It was also shown that AVs may significantly reduce the number of road accidents through the use of advanced sensors. AVs may not be as good at reducing the severity of accidents as they seem to be at reducing the number of accidents. The severity may remain unchanged or even increase as a result of the adoption of AVs. Finally, AVs have a significant potential to increase road safety, yet more research and development are required to ascertain that AVs can perform safely.

6.2. Policy and industry recommendations

Regarding the recent advancements related to the legal frameworks of the AV operations reviewed in this research, and with regards to the opinions of the professionals participated in the survey of this study, the following policy and industry recommendations could be considered.

Introduction and regular update of the Safety Acts and legal frameworks in both country and continental levels that would govern the usage of AV's. Providing opportunities for close cooperation of the researchers with legislators, industry professionals, car manufacturers, and the transportation-related agencies in the field. Such opportunities could be the establishment of industry bodies or national policy groups to ensure engagement.

Translating legal frameworks and regulations for public individuals in order to (a) familiarise them with the technologies adopted in automated driving and their expected benefits and drawbacks, (b) prepare them for the prospective changes required in travel behaviours and society. This is an important change that is required as it education and public support will be crucial to the success of AV's. Finally, establishing regulatory frameworks regarding car insurance and accidents for AVs and the responsible group or agency who should bear the highest legal responsibilities in the case of AV accidents.

6.3. Weaknesses

It is important to discuss some of the main weaknesses of the approach used and to inform the reader of any caveats they should consider when interpreting the work. The main challenge of this study was finding experts with relevant expertise in the field. That is why we have termed our survey respondents professionals from the field rather than experts, as perhaps one might expect to use the term expert in such a research endeavour. Despite every effort being made to make the survey as short as possible, there was a very low willingness to participate. In total, around 5000 personal emails and LinkedIn messages were sent to collect 300 responses. Since all of the invitations were prepared and sent without the help of any agency or automated system, this process took much time and effort to engage in and complete.

Data curation led to the elimination of 115 responses, which reduced the sample size to 185. This increased the chance of getting data skewed, and therefore, it required extra time and tests to make sure the data had the required goodness of fit for evaluation. The topic of the research is fast-growing, and there is a chance that the advent of new sensor technologies related to the production of AVs has demonstrated some contradictions to at least some of the findings of this paper. This is out of the authors' control. This issue has already affected this research, and it required the authors to run extra evaluations to ensure the materials presented in the paper were as recent as possible.

The difficulties encountered regarding the data collection prevented the authors from running a second and third survey round (like in the Delphi method) to ensure that the professionals had the opportunity to modify their opinions if required. A further limitation that should be considered by the reader is the reliability that the 185 professionals selected for the survey were indeed professionals. As was shown in [Table 2](#) every effort was made to try and verify that these responses were indeed from professionals, one should be mindful of this weakness when interpreting the results presented in our paper.

6.4. Future research directions

Regarding the knowledge and experience gained from this study, the following are recommended for future research in this field. Where possible, running a Delphi survey will help professionals consider the recent advancements in the fast-growing science and industry of AVs and apply them to the next round(s) of the survey. This would also provide the professionals with an opportunity to observe other professionals' opinions, review their own opinions, and modify their own opinions in the next round of the survey where required.

Our study revealed that AVs might have the potential to reduce the number of accidents while resulting in accidents of higher severity. Therefore, future studies are recommended to take the modelling approach to assess the severity of accidents and evaluate the outcomes related to fewer accidents and higher severity. Finally, investigations into a broader range of the technical issues related to AVs' application and modelling their impact on accidents would further help identify more of the possible outcomes of the AV operations and fill in the gaps in this regard.

CRedit authorship contribution statement

Amin Rezaei: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Brian Caulfield:** : Conceptualization, Methodology. : Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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