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Public Perception of the Introduction of Autonomous Vehicles

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Abstract: Autonomous vehicles (AVs) will transform transport, but public opinion will play a key role in decisions on how widely and quickly they are adopted. The purpose of the study presented here was to investigate community's views on that transition. As a method for primary data collection on public awareness, attitudes, and readiness to use autonomous cars, survey was conducted in Saudi Arabia. Following that, we used statistical tools to analyse responses. Our findings indicate that the participants are largely receptive to using new technologies and had favourable attitudes towards the transition. Ordinal logistic regression model showed a wide variation in public opinion regarding the expected benefits that may accompany the transition. Our findings reveal that awareness of AVs' benefits is positively correlated with the age of participants. Perceived costs on one side, and convenience and safety on the other, were found to have had a substantial impact on the opinions of the participants. Investigation presented here shows a sample of the public's perception of AVs in Saudi Arabia. This can guide the development of AVs and their deployment in that region as well as worldwide.

Keywords: autonomous; vehicle; electric; survey; smart city; Saudi Arabia; intelligent transport system

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1. Introduction

Autonomous and electrical vehicles (EV)s are reshaping transport sector. They are subsystems of the future intelligent transport systems (ITS)s [1] and have the potential to bring safer, more efficient, environmentally friendly, and sustainable transport. We are in a transition from personally owned means of transport towards a mobility as a service (MaaS) platform. Thanks to AVs, we will have more efficient transport, with less pollution and better safety. Electric cars make it feasible to have green transport if the electricity used for them is green [2]. EVs are reducing greenhouse gas emissions from internal combustion engines (ICE)s. Thanks to MaaS, we will have a smaller number of vehicles on the road and the same benefits introduced by AVs. However, the introduction of AVs on the highest level of autonomy, with no driver involved, brings a number of ethical, moral, and legal issues that must be resolved. MaaS has its own level of maturity, and it varies around the world. As with any new product, public acceptance of a new technology or a new service (in this case, mobility) is a key factor in its implementation. MaaS is available in urban areas in Europe, North America, and Australia, and increasingly in Asia as well. A field investigation into maturity requirements to operate mobility as a service in Rome [3] has shown various limitations. One of them is the low public readiness to pay for the service. Electrical and autonomous vehicles will be subsystems in new mobility solutions, but they all have their own technology acceptance frameworks. In all of them—AVs, EVs, and MaaS—information and communications technology (ICT) plays a key role. Typical MaaS users belong to social groups which are ICT users, regular commuters, and millennials. Global introduction, maturity, and acceptance of MaaS is subjected in many other studies, like one in Sydney [4]. AVs and EVs are just transport modes in multimodal MaaS and subsystems in intelligent transport systems.

ICT supports vehicles through a connectivity and networking system known as a vehicular ad hoc network (VANET). VANET is also a subsystem in the intelligent transport system. ITS monitors traffic using Internet of Things (IoT) and will soon control it with the aid of artificial intelligence (AI). EVs have few hybrid technologies while AVs are categorized into five, according to the National Highway Traffic Safety Administration [5], or six levels of autonomy, as per the Society of Automotive Engineers (SAE) [6] taxonomy.

According to the newest SAE classification, from 2021, AV at level 0 has no autonomous functions, and the driver always has full control of the car. At level 1, the car has some autonomous features like automated braking or electronic stability control, but the driver is still in charge of steering. At level 2, the car can accelerate or steer on its own, but the driver still needs to be focused and prepared to take over at any time. Level 3 vehicles can perform all driving activities under certain circumstances, but the driver must be ready to take over when necessary. The driver must still be present, even when the vehicle is autonomous at level 4, and take over in some circumstances, like inside a specific geographic area, or in certain weather conditions. When a vehicle reaches level 5, it is completely autonomous and does not need a human driver.

All technological innovations are disruptions on the market and the automotive sector must respond with new business models. As AV and EV transitions are global, we have applied a hard systems approach (HSA) and soft system approaches (SSAs) in management, to predict and propose future pathways. HSA is used to deal with the AV transition in terms of technology, referring to hardware and software—sensors, actuators, processors, control software, and AI algorithms—used to make vehicles autonomous. AI algorithms for real time processing, self-driving, are still being improved, as it is an evolving process [7]. Big data processing for driving must be performed in real time, i.e., fast enough in the defined time frame, known as the response time. That response time should be the same as humans' reaction time (RT), 180–200 ms, as given in [8], or better. Our auditory RT (ART) is shorter than visual RT (VRT). ART is around 140–160 ms, which is less that of VRT. This is the reason that active safety applications, found on the level 1 and 2 of the AVs, use audio warning messages.

Finally, not everyone will decide to invest in full autonomy. At the lower levels, levels 1 and 2, driver warnings and many other applications for active safety are already in place and there are no issues in adoption. Issues arise at the highest levels, levels 4 and 5, i.e., with full automation. AVs on that level are mobile robots on the road. At levels 3 and 4, the driver is expected to take over control of the vehicle. The other parameter, driver response time to take over control of the vehicle, is also extremely important, as presented in the "Designing for the Extremes: Modeling Drivers' Response Time to Take Back Control From Automation Using Bayesian Quantile Regression" [9].

Figure 1a shows an electrical vehicle designed by RMIT University students, while Figure 1b shows an RMIT autonomous vehicle. AV software was developed for a commercially available electrical vehicle. A MATLAB program was running on a laptop sitting in the driver's seat, replacing the driver. LiDAR was used to map the environment. We have developed sampling-based robot motion planning algorithms and tested them with our AV [10].

Applying HSA, we concluded that the technology is ready for the transition. The next step was to apply SSA. SSA is generally used for solving management and business problems. In the scenario of full AV introduction, SSA is used when handling moral and ethical dilemmas and concerns with governmental rules and regulations. Since mobile robots, i.e., our autonomous vehicles, coexist and interact with the environment and other AVs and non-AVs on the road, we must deal with ethical and moral issues, and we require a regulatory framework to approve the application of those intelligent systems.

(a) (b)

Figure 1. (**a**) Electrical vehicle designed by RMIT University students. (**b**) Autonomous vehicle with control software designed by RMIT University students.

In any system, all stakeholders are involved in making decisions. They have different views of the systems, enabling new ways of solving problems and moving forward. With SSA, we are managing the transition to autonomous vehicles by working with all parties, including the government, traffic authorities, manufacturing companies, and the public. The introduction of autonomous vehicles has raised concerns about user safety, costs, reliability, sustainability, and ride comfort [11]. We use the soft systems approach because it is a method for comprehending and undertaking difficult issues with a lack of clear solutions or agreements. The SSA approach is defined by a focus on comprehending the dynamic and complex nature of real-world problems. It develops workable solutions that consider the requirements and viewpoints of stakeholders. The SSA approach emphasises the use of qualitative and participative data collection and analysis. These techniques, which could include interviews, focus groups, presentations, and seminars are used to collect primary data about the experiences, viewpoints, and requirements of various stakeholders. The use of conceptual models and diagrams to describe and comprehend complex systems and problems is another important SSA component. Relationships between various components are represented using the system's approach, which can also contain conceptual frameworks, mental models, and causal loop diagrams. They are used to identify important drivers and feedback mechanisms. Due to the complex and dynamic nature of the systems, the SSA approach is especially well suited for the management of the introduction of autonomous cars. Following that, we have conducted longitudinal surveys. They have included participants from all stakeholder groups.

AVs are subsystems of ITSs, which are subsystems of smart cities. Smart cities are metropolitan areas that use cutting-edge technology to enhance quality of life among citizens and economic growth. They use the Internet of Things (IoT), which generates big data, ICT, and AI to process data. As they have the potential to revolutionise transport, decrease traffic and pollution, and enable new mobility services, autonomous cars are seen as a crucial part of smart cities. The futuristic city of NEOM, which is being constructed in Saudi Arabia, is one example of a smart city that is being developed [12,13]. The 26,500 square mile metropolis of NEOM is built to be a global hub for cutting-edge technologies [14]. Autonomous vehicles will be used for transport services and to link the city to the surrounding areas. The deployment of autonomous vehicles in NEOM is anticipated to provide several advantages, including greater mobility for citizens, increased safety, and decreased congestion and pollution.

AV technology is ready for deployment when the following four stages of the technology acceptance model (TAM) are completed: engineering, legal, moral, and ethical. They are shown in Figure 2. The engineering stage has bidirectional links, because we have feedback involved in the continuous engineering improvements based on regular evaluations, technology progress, and changes in customer requirements.

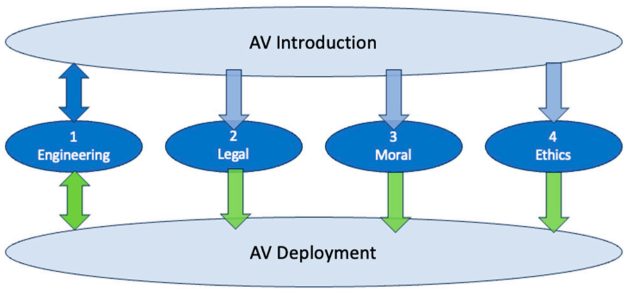

Figure 2. TAM with stages in AV technology deployment.

Autonomous vehicles, at all levels of autonomy, play a significant role in the development of modern transport systems [15]. Clarifying issues, especially from stage 3 to stage 5, as shown in Figure 2, is the most significant obstacle to AV adoption, not the technical aspect [16]. Despite the amount of potential effective solutions from the adoption of self-driving vehicles in improving road safety, we need to highlight benefits associated with self-driving vehicles. According to previous studies, there is notable concern among drivers about self-driving vehicles and many of them are hesitant to use them [17]; however, drivers welcomed active safety through driver warning systems [18]. Therefore, the basic benefits of AVs, such as increased safety and fuel efficiency, may not be enough [19]. We believe that increased public awareness of AVs may contribute to promoting this technology and advance its adoption.

While some efforts were made to understand why people would use AVs or to what extent social and personal factors may influence this acceptance, few of them have measured the extent of familiarity with AVs. The community's attitudes and readiness to purchase AVs have an impact on when and how autonomous technologies will be adopted. The presented study aims to fill in this research gap and obtain stakeholders' views. We investigated public awareness of AVs and measured consumers' readiness for the transition to new technologies in Saudi Arabia. Up to now, there has been a lack of studies on public opinion about autonomous vehicles in the Middle East.

2. Materials and Methods

Our methodology defines various approaches and procedures used in finding new knowledge and relationships in investigated domains across engineering, social, business, medical, and other. In natural sciences, we use mathematical apparatus in modelling systems. Unfortunately, mathematical formulas cannot be applied to all systems. In such scenarios, we use data collection for model development and further analysis. Three methodologies could be applied for this type of research: qualitative, quantitative, and mixed methods.

The qualitative approach is used to collect non-numerical data such as opinions, emotions, and behaviour. Using a quantitative method, numerical data types are collected that can be quantified, measured, and graded. In this case, after data collection, statistical analysis is used for data interpretation, correlation, presentation, or system structure and behaviour. In the next step, inductive reasoning could be applied. It starts with specific or particular observations to determine general findings. Finally, there is a combined, mixed method. We have used a comprehensive approach in combining both qualitative and quantitative methods. Open-ended questions were used to collect qualitative data, and Likert scale survey questions to collect quantitative data. Combining qualitative and quantitative research methods can achieve better results.

A questionnaire is a primary research method used to identify public perception about AVs due to its ability to gain in-depth opinions [20,21]. In 2022, a survey was conducted on the topic of AVs introduction in Saudi Arabia as a follow-up to the KSA survey from 2021. Our investigation methodology was to conduct a cross-sectional survey first. A cross-sectional study is an approach for looking into responses from all stakeholder groups at a certain point in time. Follow-up investigations are longitudinal studies, collecting data repeatedly over a time. The first cross-sectional survey conducted in KSA was during the COVID-19 restrictions in 2021 and managed to obtain 213 responses, which was already reported. This paper is a report on the second longitudinal survey conducted the following year, in 2022. Differences in findings are highlighted in this report.

The purpose of the study was to collect primary data and compare survey results from one country to another and in different time periods. We are planning to conduct multi-year longitudinal studies. The results will be utilized to assist legislation preparation, technology development, and to increase public awareness. Throughout this section, we outline the survey instructions, the questionnaire content, the demographic data of the participants, the limitations, the validity, and the model selection.

The questionnaire, with 31 questions, was designed to collect de-identified data. Responses were collected through a secure survey design system, Qualtrics. The investigation was approved by the RMIT University Ethics Committee (#23507). All recommended best practices for executing the survey were followed. The KSA survey was in Arabic and all mandatory instructions were translated. In the pamphlet, we explained the purpose of the survey and reminded respondents that participation is voluntary and that their comments would be kept private and anonymous. After presenting a brief description of the survey, the participants were asked about their age and whether they are drivers themselves. The survey would end at this point for a given participant if that participant was underage (younger than 18 years of age) or did not drive before. It was mentioned to participants that the survey would take about 7–10 min to complete. Contact details of the principal investigator were given for any possible enquiries. The survey started when a participant's consent was obtained. Each participant was free to withdraw at any time. We wanted to measure participants' familiarity with AVs, expected benefits, and concerns surrounding adopting autonomous technology.

The questionnaire had four sections. Demographic data were collected first, including gender, age, educational levels, stakeholder group, and current mode of transport used. The next set of questions was aimed at assessing the depth of the respondents' familiarity with the AVs. Afterwards, a set of questions were focused on respondents' expectations about AVs, car ownership in the future, preferred level of automation, time to buy, and timeframe for the transitions in Saudi Arabia. The third section covers anticipated benefits and risks from the transition into autonomous technology.

In the last 15 questions, the survey proceeded with enquiries into the importance of AVs' specific functionality, such as safety, comfort, performance, and system security. The use of quantitative data is the principal focus of the questionnaire and they are collected through multiple-choice questions. The participants were also asked two open-ended questions used to collect qualitative data. They were asked to give their opinions about the benefits and the risks of AV transition: "Please list the benefits you can predict from this transition" and "Please list the risks you can predict from this transition". All questions measured different attributes, and the scales of each are given in the Table 1.

Table 1. List of survey questions, with each measured attribute and their scales listed.

No.	Question	Attribute	Scale
1	What is your gender?	Gender	1–2
2	Which age group do you belong to?	Age	1–4
3	What is your highest education level?	Education	1–5
4	Your current mode of transport?	Transport Mode	1–2
5	Which key stakeholders' group do you belong to?	Stakeholders	1–4
6	What is your management role in your organisation?	Management	1–6
7	Have you heard about or seen an autonomous vehicle?	Awareness	1–3

Table 1. *Cont.*

No.	Question	Attribute	Scale
8	How do you see car ownership in the future?	Ownership	1–4
9	What is your preferred level of automation?	Preferences	1–6
10	Which of the following levels of autonomous vehicles you are willing to pay for?	Preferences	1–6
11	When do you plan to buy an autonomous vehicle?	Attitude	1–5
12	When do you see that the transition to autonomous vehicles will happen?	Vision	1–5
13	To what extent do you see benefits from the transition to autonomous vehicles?	Benefits	1–5
14	Please list the benefits you can predict from this transition:	Benefits	Qualitative
15	Do you see risk from autonomous vehicles transition?	Risk	1–5
16	Please list the risks you can predict from this transition:	Risk	Qualitative
17	Out of all attributes of autonomous vehicles how important is the price on the scale 0 (not important) to 100 (the most important):	Price	1–5
18	Out of all attributes autonomous vehicles how important is the safety in driving, using new technology, on the scale 0 (not important) to 100 (the most important):	Safety	1–5
19	Out of all attributes of autonomous vehicles how important is the comfort, i.e., no need to drive, using new technology, on the scale 0 (not important) to 100 (the most important):	Comfort	1–5
20	Out of all attributes of autonomous vehicle how important is the more efficient, i.e., quicker transport, using new technology, on the scale 0 (not important) to 100 (the most important):	Efficiency	1–5
21	Out of all attributes of autonomous vehicle how important is the more sustainable transport, i.e., less pollution, less CO_2 and less global warming, thanks to new technology, on the scale 0 (not important) to 100 (the most important):	Sustainability	1–5
22	Out of all attributes of autonomous vehicles how important is the privacy on the scale 0 (not important) to 100 (the most important):	Privacy	1–5
23	Out of all attributes autonomous vehicles how important is the anti-hacking software or hardware on the vehicle, using new technology, on the scale 0 (not important) to 100 (the most important):	Cyber security	1–5
24	Out of all attributes autonomous vehicles how important is the accuracy in driving, timing of arrival, best path selection, on the scale 0 (not important) to 100 (the most important):	Accuracy	1–5
25	Out of all attributes of autonomous vehicles how important is the performance, i.e., driving uphill, using new technology, on the scale 0 (not important) to 100 (the most important):	Performance	1–5
26	Out of all attributes of autonomous vehicle how important is the car ownership, i.e., own a car, using new technology, on the scale 0 (not important) to 100 (the most important):	Ownership	1–5
27	Out of all attributes of autonomous vehicle how important is the carsharing options, i.e., share the car, using new technology, on the scale 0 (not important) to 100 (the most important):	Carsharing	1–5
28	Out of all attributes autonomous vehicles how important is the cost of transport in riding, using new technology, on the scale 0 (not important) to 100 (the most important):	Cost	1–5
29	How important is the impact on labour in car industry, i.e., regarding drivers, mechanical shops, driving schools, AV software and hardware engineers, on the scale 0 (not important) to 100 (the most important):	Employment	1–5
30	How important are the health benefits, i.e., less traffic fatalities, decreased emissions, lower traffic congestions, and increased mobility for people who are unable to drive, on the scale 0 (not important) to 100 (the most important):	Health	1–5
31	How important is the physical activity, i.e., people who will be using new technology for door-to-door transport, will walk less on the scale 0 (not important) to 100 (the most important):	Health	1–5

For the purposes of this study, two dependent variables were used based on the following questions: “To what extent do you see benefits from the transition to autonomous vehicles?” and “To what extent do you see risks from the transition to autonomous vehicles?”. These questions aim to analyse the public’s awareness of AVs. One of the hypotheses is that those who are better informed of the broader benefits of driverless transport could have a higher interest in buying an AV with a higher level of automation sooner, compared to those who are less informed of the overall benefits.

In terms of the grouping strategy, the categories for user demographics, such as gender, age, and education level were designed based on previous studies in the field [22]. The inclusion of these variables was intended to test whether there are any differences between the categories in relation to the adoption of AVs. For example, previous studies found that age and gender might affect consumers’ willingness to use driverless vehicles; for example, those who are men and young are more likely to have positive attitudes towards AVs [23–26].

In addition, the survey included two clustering questions that specify the typical members of major stakeholder groups and their roles in their organisation. This provides a better quality of findings through classifying them according to specific groupings. That enables us to determine the causal relationships between the public’s awareness of AVs and their status of belonging in various stakeholder groups.

Further to this, prior knowledge of AVs was examined, as participants were asked whether they have ever heard about or seen an autonomous vehicle before participating in this survey. This allowed us to better understand their perception of AVs. For example, those who have seen AVs before have different biases from those who have just heard about AVs, and subsequently from those who have never heard about or seen AVs at all. These three distinct categories were beneficial in categorising responses into groups for representing their varied perception of AVs based on prior knowledge.

In terms of customer opinions and preferences, we asked about the willingness to buy a vehicle with a certain level of AV technology. We asked about the timing of the purchase as well as opinions of car ownership. Finally, we enquired about their expectations for the timing of full AV introduction in Saudi Arabia.

The questionnaire was distributed online to residents of Saudi Arabia and was accessible for two weeks, starting on the 20 June 2022 and closing on the 3 July 2022. During this period, a total of 115 surveys were finalised, but just 108 were considered to be valid, among respondents aged 18 and over. Out of 108 participants, 17.6% were women and 82.4% were men. Nobody selected the “prefer not to say” option.

Table 2 presents the demographic characteristics of the 2022 Saudi Arabia survey. Since each group has more than 15 samples, it enables us to include an independent samples *t*-test for each demographic to compare the gender differences. The results showed a range of credentials in terms of age, level of education, and current management role. The respondents’ ages ranged from 18 to over 55, where the majority of participants (40.75%) were in the age group of 26–35 years old (compared with 19.25% nationally [27]). The younger age group, aged 18–25 years old, represents 22.22% of the sample (compared with 13% nationally [27]), while middle-age group, aged 36–55 years old, represented 36.11% of the sample (compared with 32.9% nationally [27]).

More than half of the participants (>52%) have a higher education level (master’s degree or another postgraduate degree). This demographic differs from the previous studies [28,29] and is higher than recent studies [30,31]. The survey has also involved a question about the currently used mode of transport. The majority of respondents (96.3%) are car owners. Just 3.7% of respondents use public transport. Respondents were from three major stakeholders’ groups, which are industry (12.4%), government (59%), and general public (28.6%).

Table 2. Demographic data of the participants.

Demographic	Gender n (%)		
	Male 89 (82.4)	**Female 19 (17.6)**	**N (%) 108**
Age group			
18–25	15(13.89)	9 (8.33)	24 (22.22)
26–35	37(34.26)	7 (6.49)	44 (40.75)
36–55	36(33.33)	3 (2.78)	39 (36.11)
Above 55	1(0.92)	0	1 (0.92)
t-test	−2.998 [0.006 ***] (−0.950, −0.176)		
Education level			
Primary school	0	0	0
High school	5 (4.63)	0	5 (4.63)
Diploma	4 (3.70)	3 (2.78)	7 (6.48)
Graduate Degree	30 (27.78)	9 (8.33)	39 (36.11)
Postgraduate Degree	50 (46.29)	7 (6.49)	57 (52.78)
t-test	−1.046 [0.304] (−0.573, 0.185)		
Transport mode			
Car owner	87 (80.56)	17 (15.74)	104 (96.3)
Use Public transport	2 (1.85)	2 (1.85)	4 (3.7)
t-test	1.118 [0.277] (−0.072, 0.237)		
Stakeholder group			
Industry	14 (12.96)	2 (1.85)	16 (14.81)
Government	53 (49.08)	9 (8.33)	62 (57.41)
Traffic Authority	0	0	0
Just Public	22 (20.37)	8 (7.41)	30 (27.78)
t-test	1.405 [0.173] (−0.187, 0.987)		
Level of Management role			
Level 0	11 (10.18)	6 (5.56)	17 (15.74)
Level 1	9 (8.33)	3 (2.78)	12 (11.11)
Level 2	10 (9.26)	3 (2.78)	13 (12.04)
Level 3	10 (9.26)	3 (2.78)	13 (12.04)
Level 4	22 (20.37)	0	22 (20.37)
Level 5 (Highest)	27 (25.00)	4 (3.70)	31 (28.7)
t-test	−2.449 [0.022 **] (−2.152, −0.185)		

Note: *p*-value is in square bracket; values below *t*-test value and *p*-value are confident interval values; ** indicate significant at *p*-value $p < 0.05$, and *** indicate significant at *p*-value $p < 0.01$.

The respondents' management role was recorded using a scoring system from the highest level of leadership or management to no management role at all. There were six levels of choice. We had the following responses: At the highest level, level 5, we had 29.5% participants. Following that, level 4 comprised 21%, level 3 comprised 12.4%, level 2 comprised 9.5%, level 1 comprised 11.4%, followed by level 0 at 16.2%. Women scored less than the men on average age (t = −2.9883, p = 0.006) and the level of management role (t = −2.4485, p = 0.022). This is due to the following reasons: (a) this study was conducted in Saudi Arabia, where women could not drive legally until June 2018 (about four years before the survey was conducted); (b) in the Saudi workforce, men have dominated this sector for decades, and the participation of women has effectively commenced in the past few years, since 2018. Accordingly, there are constraints in our survey. Most of the participants were male, comprising 82.4% of the respondents, compared to 57.76% nationally [27]. Despite the fact that the difference in the genders' sizes does not generate any bias, this limits the representation of one gender. However, the percentage of women participants in this study is higher than in recent studies, as reported in [31]. According to the National news [32], Saudi women represent approximately 35% of the Saudi workforce.

Another constraint is that only one response was recorded from a participant older than 55 years. This is most likely because the study was distributed over social networking websites and online automotive groups. In Saudi Arabia, this older age group is hard to be found there. Most of the participants were in the age interval of (25, 55) years, representing 76.7% of the sample (compared with 51.86% in population nationally [27]).

Looking at the population of Saudi Arabia, the majority of people are aged between 25 and 55 [27]. Therefore, it could be the most important group in which to analyse opinions surrounding the adoption of and interest in driving AVs in the coming years. This should not be considered as a constraint when drawing conclusions from the survey data. In addition, to overcome this issue, we have merged two age groups, "36–55" and "above 55". The new group is called age "above 35".

Another constraint that should be considered is that no responses have been recorded from the traffic authorities; they are one of four major stakeholder groups. It could be a cause of security restrictions. This group might not be allowed to participate in any survey without permission from higher authorities. In Saudi Arabia, people working for traffic authorities are working under government regulations. Since almost 60% of responses were recorded from respondents in the government group, this percentage could be used to represent both groups.

No responses have been recorded from drivers with a primary school education level. This is most likely because the Kingdom of Saudi Arabia requires citizens to attend school and gives grants for those who study higher education. Accordingly, this is not a real constraint.

Another constraint is that 96.3% of the respondents are car owners. That does not provide a good representation of people using public transport. This could be due to the limited options available for travellers, since moving around in Saudi Arabia often requires a car. It is not a surprise that taxicabs are prevalent in the Kingdom. Transport by rail in Saudi Arabia is a relatively new option and only exists in some parts of the country as a link between cities. This will not cause bias, but it does limit the representation to one transport mode.

Although that there are some limitations associated with the selection of participants, our study has gathered responses from individuals holding roles in diverse levels of management in the industry, government, and public sectors. This has provided a wide range of responses. It enables us to see the differences between the major stakeholder groups. More than 90% of participants have heard about self-driving vehicles before participating in this survey, as shown in Figure 3. The fact that we obtained responses from people who reported prior knowledge of the existence of AVs promotes the validity of the study. Their responses to the questions on their opinions and preferences surrounding AVs were answered with better knowledge as a result of their prior awareness. Alongside these points and in contrast to the existing studies, there was diversity in terms of their age and education levels. Therefore, the validity of this study is maintained due to the variety obtained in respondents' categories and demographics (see Table 2).

The fact that this survey was conducted in Saudi Arabia means that it does not represent the perceptions among the global population. We compared our results with the findings of a survey conducted in Saudi Arabia the year before and with other surveys of a similar nature conducted in other nations around the world. The sample of survey participants is sufficiently diverse to reliably represent the general population. Therefore, we anticipate that our investigation provides a contribution to the general research on this emerging technology.

We used classical statistical methods in our data processing because they have several advantages. Classical statistical methods often provide results that are easy to interpret, making them accessible to a wide audience. Considering the recent changes in the law surrounding women drivers in Saudi Arabia, we specifically utilized a *t*-test to explore the potential differences between men and women in terms of their age group, education level, transport mode, stakeholder group, and level of management role. This choice aligns with the recognition that demographic factors, including age and gender, were indicated in previous research as influential factors affecting individuals' comfort, trust, and acceptance of autonomous technologies. By strategically implementing the *t*-test we sought to uncover and address any demographic variations that might have impacted the participants' responses in our study. Also, we used a *t*-test to determine the preferred level and willingness to pay for AVs to measure the overall interest in owning and willingness to pay for self-driving vehicle technology. Other descriptive statistics were summarised to gain a better understanding of opinions, concerns, and general acceptance among Saudi drivers. The model that we have used is explained in the following section.

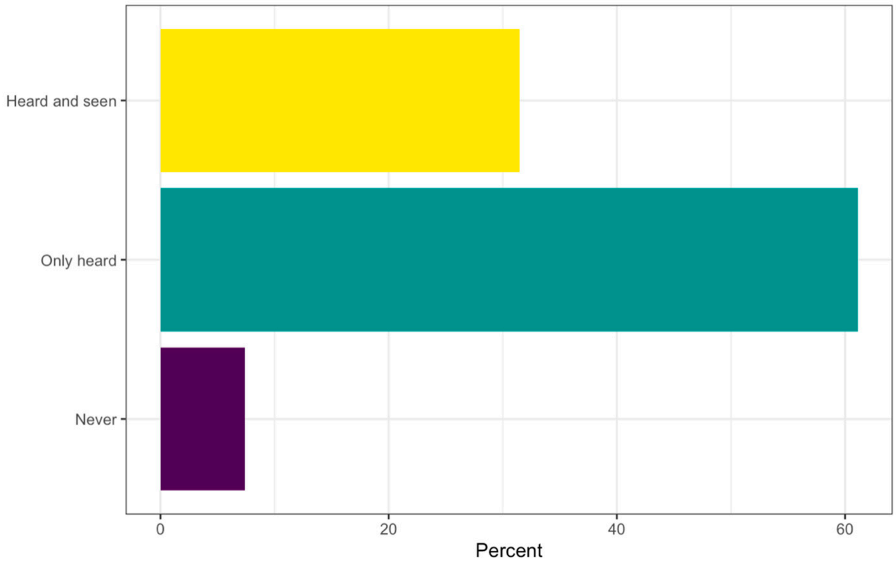

Figure 3. Percentage of people with the prior knowledge of Avs.

Model Approach

An ordinal logistic regression (OLR) approach was applied to examine significant factors that could help in understanding the level of awareness of AVs in Saudi Arabia. We used the benefit perception of AVs as a dependent variable, and this is defined through the benefit responses seen from the transition to increased use of AVs. OLR is a widely used classification method with several key advantages. Firstly, OLR is useful when the dependent variable is classified into three or more ordered categories. For example, the benefits of adopting autonomous technology in this study, with a 5-point Likert scale, is a perfect context for the application of the OLR method. Secondly, the OLR method does not need to assume equal intervals between scoring categories, unlike other regression models. Thirdly, the OLR method includes the ranking information in the dependent variable when returning the information on the contribution of each independent variable based on the cumulative-odds principle. Note that the interpretation of an estimated regression slope for OLR is somewhat complex. It is considered to be one of the most respected methods in the field of data analytics.

Before we fitted the ordinal logistic model, it was necessary to decide what outcomes to compare and what the most reasonable model was for the logit. In our case, we wanted to compare the lower probability with higher probability of public perception of benefits from the transition to increased use of AVs. Therefore, the proportional odds model was deemed to be suitable due to the following attractive characteristics: (a) instead of considering the probability of an individual event, it considers the probabilities of that event and all events that are ordered before the focal event in the ordered hierarchy, and compare it to the probability of a larger response; (b) it provides explainable and straightforward coefficients of the regression due to the transformations used during the estimation and the log odds interpretation of the output.

The coefficients and the intercept have different interpretations in the OLR model. Unlike simple linear regression, in the OLR model we obtain (*J-1*) intercepts, where *J* is the number of categories in the dependent variable. The intercepts can be interpreted as the expected odds in the listed categories, whereas the coefficients of the regression will be interpreted in terms of the increase in the log odds. Note that a lower cumulative odds value corresponds to fewer observations in the lower score categories, which results in a trend for higher scores. To understand more how to interpret the coefficients, let us first establish some notation and review the concepts involved in ordinal logistic regression.

Let Y represent the response variable, in this case, "perceptions of the benefits associated with the transition to increased use of AV", on a scale with J-ordered levels of categories (i.e., 1 to 5; with 1 = no benefits at all and 5 = associated benefits of very high level). Then, we use $P(Y \leq j)$ to denote the probability of Y, falling at or below a particular level, with j taking values from 1 to J. In this context, Equation (1) expresses the odds of Y being less than or equal to a specific level.

$$\frac{P(Y \ \leq j)}{P(Y > j)} \tag{1}$$

Given that $P(Y > j)$ is zero, and division by zero is impossible, the logarithmic function is introduced. Consequently, the log odds, often referred to as the logit, is defined by Equation (2).

$$log\left[\frac{P(Y \ \leq j)}{P(Y > j)}\right] = logit\ [P(Y \ \leq j)] \tag{2}$$

The partial proportional odds can be parametrized as given in Equation (3).

$$logit\ [P(Y \ \leq j)] = \alpha_{j0} - \beta_1 x_1 - \cdots - \beta_p x_p \tag{3}$$

where α_{j0} is the model intercept and $\beta_1 \ldots \beta_p$ are model coefficient parameters representing the slopes with p independent variables for $j = 1, 2\ \ldots,\ (J-1)$. More details on ordinal logistic regression can be found in textbooks on logistic regression models [33,34]. The here-presented evaluation, plots, and analysis depict the distribution of results for most of the questions.

3. Results

A total of 115 participants completed the survey; 15 of the respondents added further commentary about the study. They suggested changes that might be made in the following longitudinal surveys. Approximately 75 participants reported their expectations surrounding the benefits and risks we might face during the transition to increased use of AVs. After inspecting the data, 7 responses were removed due to incomplete answers, resulting in a final sample of 108 responses. Although 7 entries were deleted, the remaining sample size of 108 is sufficient enough to perform the analysis.

Participants' responses to the question related to prior knowledge of AVs revealed that the majority of them (more than 90%) have already heard about autonomous or self-driving vehicles before participating in this survey. However, only 30% of respondents have previously seen AVs, as seen in Figure 3. Furthermore, the respondents' age and level of education serve as the key measures for comparison when examining their AV-related concerns, since these two characteristics were identified as having a significant impact on respondents' perceptions of AVs, as seen earlier [28]. Therefore, these two factors can be compared to the initial question of the participants' prior knowledge of AVs.

Figure 4 shows the age groups of the participants compared to their prior knowledge of the term "autonomous vehicle". The above-35 age group had the largest proportion of respondents. However, for the younger age groups, there was a lower proportion of those who had never heard about AVs compared to those who have at least heard of them; those aged 18–25 years comprised approximately 20% of the respondents compared to around 39% respondents in the 26–35-year-old age group who had heard about and/or seen AVs. It is worth noting that the 26–35 age group had the highest subset of those who reported having seen AVs in real life. Additionally, the initial question of the participants' prior knowledge of AVs can be also compared to their respective highest levels of education. As shown in Figure 5, there is a clear correlation between the level of education and an awareness of AV technology.

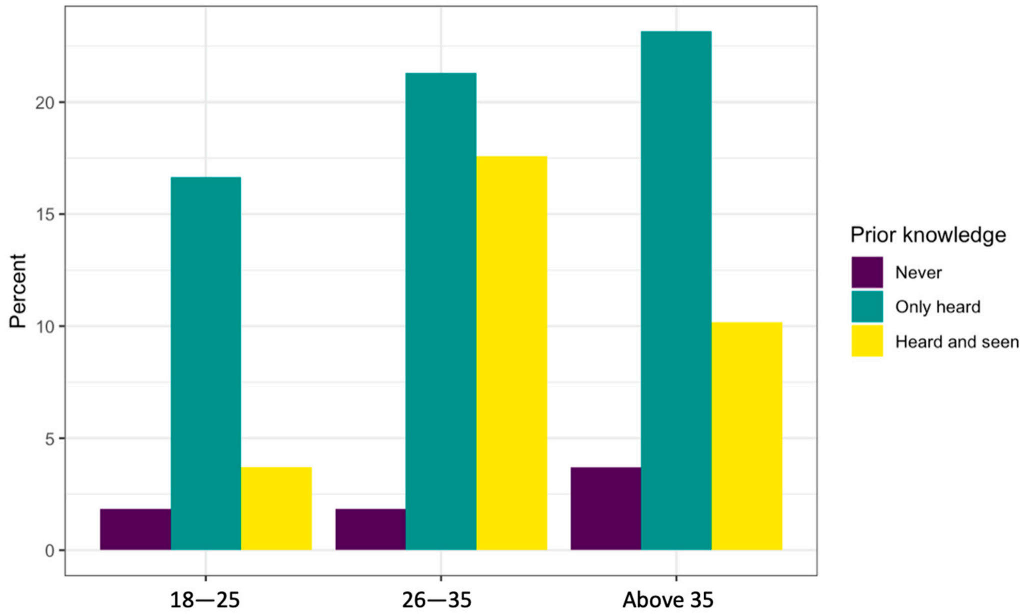

Figure 4. Comparison of age group and prior knowledge of AVs.

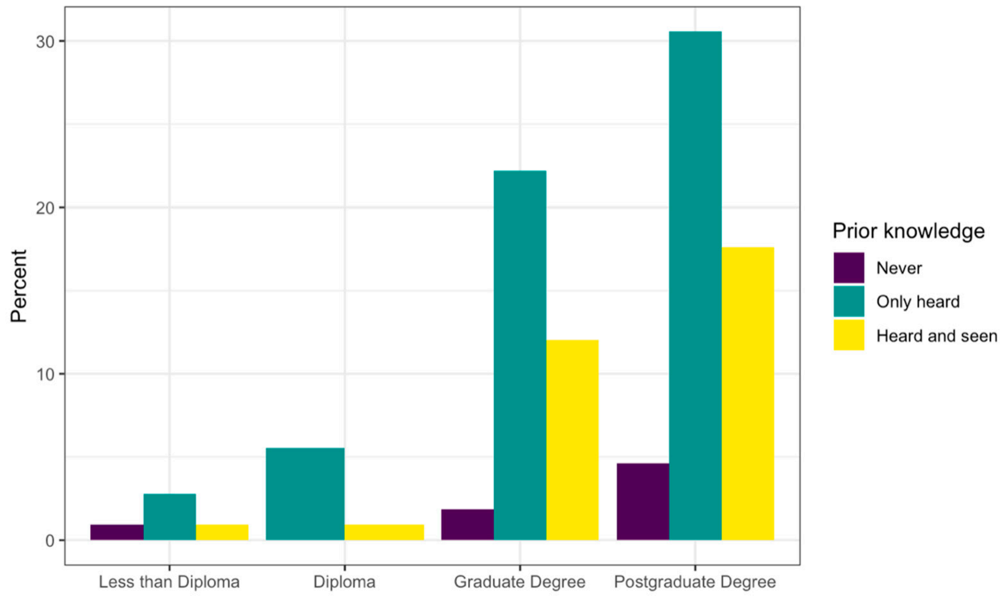

Figure 5. Comparison of education level and prior knowledge of AVs.

Two further questions were asked to gauge the respondents' interest regarding the preferred level of autonomy. Table 3 presents the percentage of each AV level accepted by respondents along with the directional hypothesis that the average acceptance of AVs is higher than level 2 (partial automation). Based on Table 3, the majority of respondents were more interested in having an automated driving system in their vehicles and less likely to buy a fully automated vehicle at level 5. Most frequently, respondents reported that they would buy a partially automated vehicle at level 4 (36.11%); this was followed by the preference for a partially automated vehicle at level 3 (24.07%). A one-tailed *t*-test also showed that the acceptance of AVs is extremely significantly higher than level 2 in relation to the preferred level and the willingness to buy, with *p*-values of 1.56×10^{-12} and 9.9×10^{-11}, respectively. The cumulative percentage of the preferred levels, from level 3 to level 5, derives an acceptance percentage of 70.37%. If we compare that with some of the other investigations, like "Why travelers trust and accept self-driving cars: an empirical study" [35], then we can see that the acceptance level is 84.4%. The difference can be explained through the fact that participants in that survey were young Chinese college students; the results cannot be generalized. Our survey also shows that young and educated people are more inclined towards the transition because they are better informed. Finally, if we calculate a cumulative percentage of preferred levels, given in Table 3, from level 2—partial automations with active safety features included—to level 5, we obtain a result of 82.41%; this is very similar to the results obtained by the other survey.

Table 3. The level of AV acceptance data.

Automation Level	Preferred Level $\mu_0 \leq$ *Level* 2, $\mu_1 >$ *Level* 2 *t*-Test, *p*-Value = 1.56×10^{-12}	Willing to Pay $\mu_0 \leq$ *Level* 2, $\mu_1 >$ *Level* 2 *t*-Test, *p*-Value = 9.9×10^{-11}
level 0	9.26%	7.41%
level 1	8.33%	9.26%
level 2	12.04%	16.67%
level 3	20.37%	24.07%
level 4	20.37%	36.11%
level 5	29.63%	6.48%

In line with previous questions, respondents were asked to report when they were planning to buy an AV and give their opinions on the timeline for the transition to AV technologies in KSA. Half of the respondents (50%) stated that they plan to buy an AV in 10 years, whereas more than 40% indicated a prediction that 2030 would be the transition year for AVs, as shown on Figure 6. As expected, the year 2030 is aligned with the SA government's long-term planning for the introduction of intelligent transport and smart cities.

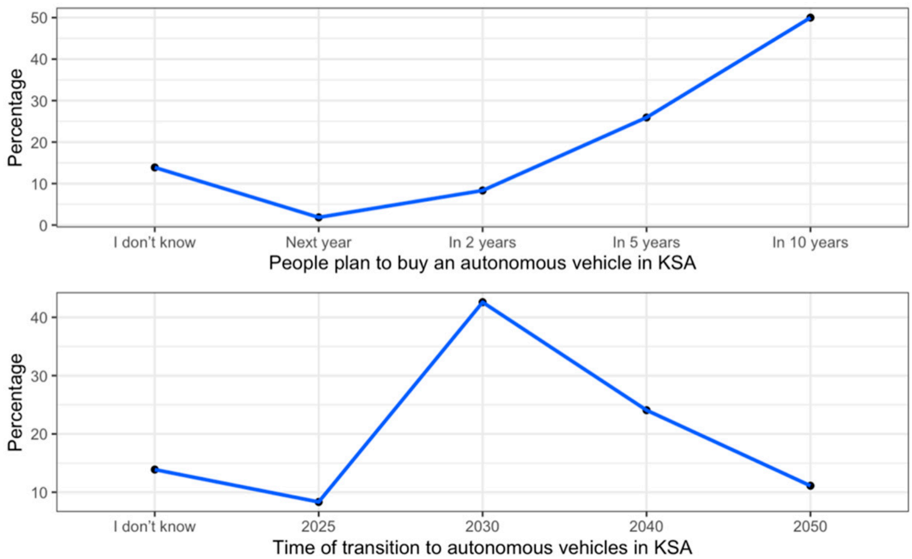

Figure 6. Percentage of responses to Q11 and Q12, i.e., timeline to buy an AV.

Participants were asked questions about the benefits and risks they predict in the transition to increased use of AVs. Based on Table 4, most had a positive attitude. When collapsed summaries (high responses versus low responses) were calculated, 51.86% of respondents answered that there would be significant benefits associated with the transition to increased use of AVs. A total of 48.15% answered that there would be minimal risks associated with the transition. There were very close percentages of respondents who answered this question by saying they predicted average benefits and risks would accompany the transition to increased use of AVs—34.26% and 39.81%, respectively.

Table 4. Percentage of responses to Q13 and Q15.

Response	Benefits	Risks
Very high	16.67%	2.78%
High	35.19%	9.26%
Average	34.26%	39.81%
Low	7.41%	41.67%
Not at all	6.48%	6.48%

Comparatively, previous research [23–26] has found that gender might impact consumers' perceptions. Thus, we include Figures 7 and 8 to display gender comparisons: a bar chart and a box plot along, with an independent samples *t*-test. In terms of general opinions, there was a clear trend observed among women and men who are more likely to have positive attitudes toward AVs. However, a between-groups *t*-test showed that significantly more women would expect benefits from this transition than men (t = 2.0629, $p = 0.04817$), whereas only slightly more women than men would expect fewer risks (t = −1.9295, $p = 0.06239$); the difference was large enough to be statistically significant at a significance level of 10%.

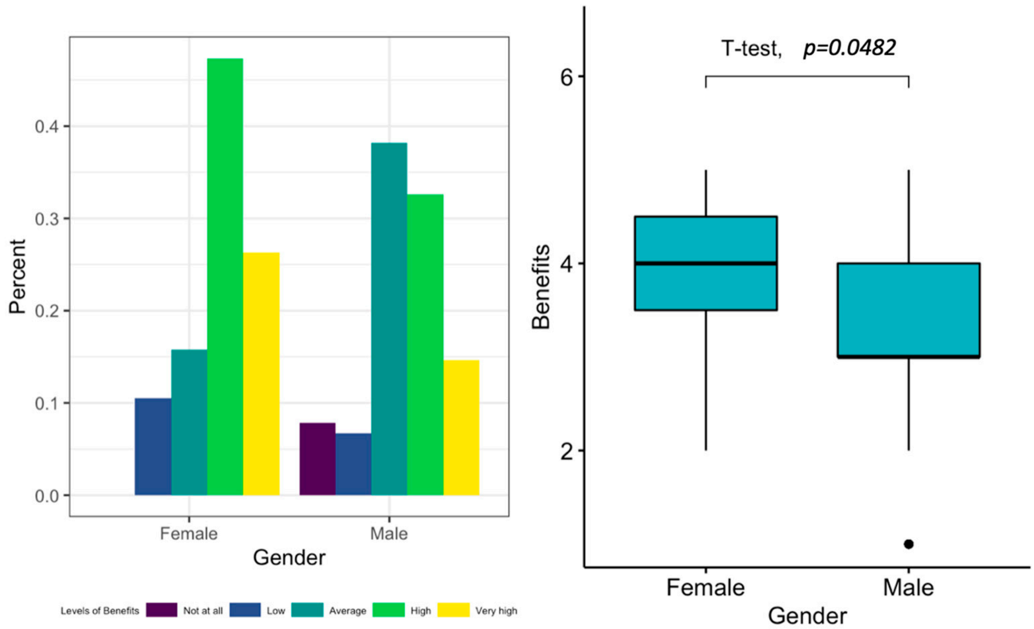

Figure 7. Correlation between gender and seen benefits from the transition to increased use of AVs.

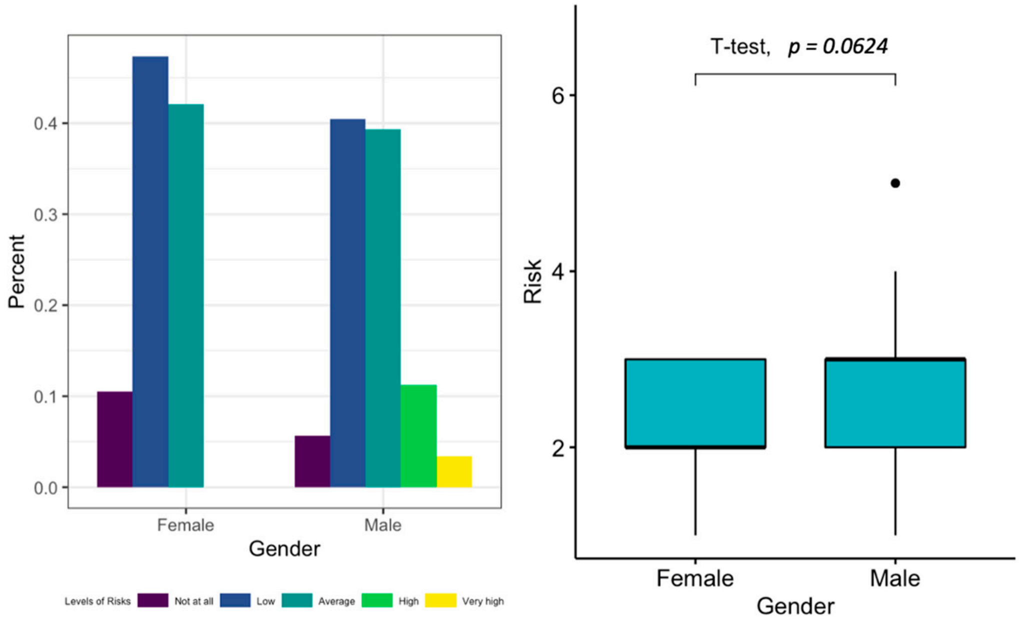

Figure 8. Correlation between the gender and perceived risks from the AV transition.

Model Building in R

Ordinal logistic regression was performed with the perceived benefits of the transition toward increased use of AVs as the dependent variable, with six predictors (gender, age, education level, stakeholders' groups, management role level, and prior knowledge). To fit the OLR model, transformation was necessary for some variables to prevent the possibility that the results of our research could be influenced by a small proportion of observations that appeared in some categories. For the gender variable, women were coded as 0 and men were coded as 1. The age variable was converted as follows: 0 = 35 or below 35, 1 = older than 35. The variable for the level of education was recoded: 0 = graduate degree or lower, 1 = postgraduate degree. The transport mode was excluded from the model to avoid misanalysis. For the stakeholder group variable, responses from the government group were coded as 0, responses from the industry group were coded as 1, and responses from the general public were coded as 2. Note that the traffic authority group was excluded, as no responses were recorded. The management role level variable ranged from 0 to 5, so the variable centred around scoring category 2 for better interpretability. That is, the 6 scoring categories (0, 1, 2, 3, 4, 5) were recoded to (−2, −1, 0, 1, 2), where the first 2 categories (i.e., level 0 and level 1) were merged.

Note that no changes are made to the variables except for rescaling. For the last predictor, "prior knowledge", participants were asked to select one of the following options: "Never", "Only heard", and "Heard and seen". The results showed that less than 10% of the respondents have never heard about AVs. Therefore, the first two categories ("Never" and "Only heard") were merged and coded as 0, whereas the last category ("Heard and seen") was kept and coded as 1.

Finally, the dependent variable "benefit" was represented with a 5-point Likert scale with the following options: "No benefits at all", "Associated benefits of low level", "Associated benefits of average level", "Associated benefits of high level" and "Associated benefits of very high level". Since there are relatively small proportions of observations at smaller values, i.e., "No benefits at all", "Associated benefits of low level", the observations from this variable were analysed based on three categories: first two categories ("No benefits at all", "Associated benefits of low level") were merged and named as "Low benefits", third category was kept and renamed as "Average benefits", and last two categories were merged and named as "High benefits" (see Table 5).

Table 5. Summary of responses to the question on dependent variable "benefits".

Original Categories	Frequency (%)	Collapsed Categories	Collapsed Summaries (%)
No benefits at all Associated benefits of a low level	7 (6.48) 8 (7.40)	Low benefits	15 (13.88)
Associated benefits of an average level	37 (34.26)	Average benefits	37 (34.26)
Associated benefits of a high level Associated benefits of a very high level	38 (35.19) 18 (16.67)	High benefits	56 (51.86)
Total	108 (100)	Total	108 (100)

The R package MASS was used to run the function polr() to estimate an ordered logistic regression model. The command name comes from proportional odds logistic regression, highlighting the proportional odds assumption in our model. We also specify that Hess = TRUE; this ensures that the model returns the observed information matrix from the optimization (called the Hessian), which is used to obtain standard errors. The coefficients from this model can be somewhat difficult to interpret because they are scaled in terms of logs. Another way to interpret logistic regression models is to convert the coefficients into odds ratios; we interpret these as we interpret odds ratios from binary logistic regression. Similarly, the coefficients will be translated into odds ratios that are either lower or higher than one (viz., (0, 1)). That, in turn—when odds ratios are lower or higher than one—means that the predicted probability is decreasing or increasing as the covariate decreases or increases, respectively. To obtain the OR and confidence intervals, we simply exponentiate the estimates and confidence intervals. A piece of code from R is shown in Figure 9.

```
## Run an OLR model
OLRmodel_Benefits= polr (Benefits ~ Gender + Age + Edu + Stakeholder +
Manage_role + Prior_knowledge, data = Auto_Vihicle1, Hess = TRUE, model =
TRUE, method = c("logistic"))
summary (OLRmodel_Benefits) #
ctable <- coef (summary (OLRmodel_Benefits))
p <- pnorm (abs (ctable [, "t value"]), lower.tail = FALSE) * 2

## combined table
(ctable <- cbind (ctable, "p value" = p))

#Test of parallel regression assumption
brant (OLRmodel_Benefits) # Probability supposed to be more than 0.05
```

Figure 9. A segment of R code used in this statistical analysis.

4. Discussion

4.1. Quantitative Data Analysis

The OLR was conducted to determine the influence of gender, age, education level, stakeholders' groups, management role, and prior knowledge on people's opinions about the expected benefits that may accompany the transition toward increased use of AVs among the population of Saudi Arabia. However, before we interpret the results, we need to check our assumptions to ensure that the model is valid. Initially, multiple linear regression was used to determine any potential issues with multicollinearity between the independent variables. A variance inflation factor (VIF) test was performed to check whether multicollinearity exists. Since none of the VIF values are greater than 10 according to Table 6 (not even close), we concluded that there is no multicollinearity in the dataset. Secondly, we need to determine whether the relationship between each pair of outcome groups is the same. Table 7 presents the Brant test which was used to test our assumption about proportional odds. Since the probability (p-values) for all variables—including

Omnibus variable, which stands for the whole model—are greater than alpha = 0.05, the proportional odds assumption is not violated, and the model is valid for this dataset.

Table 6. Assessment of multicollinearity using collinearity statistics.

Coefficients	VIF
Gender	1.132113
Age	1.379381
Edu	1.246984
Stakeholder	1.173990
Manage_role	1.251908
Prior_knowledge	1.153070

Table 7. Results of OLR slope coefficients using perceived benefits as dependent variables.

	Parameter Estimates	95% Confidence Interval		Brant Test
Main Effects		Lower Bound	Upper Bound	Probability
Gender = 1 [Male]	−1.4384 (0.6226) ** 0.2373	0.06419989	0.7619351	0.19
Age = 1 [Above 35]	0.5350 (0.4709) 1.7075	0.68659532	4.3870034	0.51
Edu = 1 [Postgraduate]	0.6460 (0.4949) 1.9080	0.73125178	5.1460243	0.62
Stakeholder = 1 [industry]	−0.3474 (0.6309) 0.7065	0.20350163	2.4520959	0.49
Stakeholder = 2 [Public]	0.8373 (0.5035) * 2.3100	0.87784387	6.4032688	0.69
Manage_role	0.1524 (0.1357) 1.1646	0.89311975	1.5241228	0.87
Prior_knowledge = 1 [seen]	1.1013 (0.4698) ** 3.0081	1.22683561	7.8105420	0.32
Intercepts				
Low benefits | Average benefits	−2.2068 (0.7116) ***			
Average benefits | High benefits	−0.2285 (0.6728)			
Model Fit				
Residual Deviance	194.3664			
AIC	212.3664			
Pr(Chi)	< 0.001			
Omnibus				0.59

Note: Standard errors are in parentheses; values below coefficients and standard errors are odds ratio values exp(β); * represents $p < 0.10$, ** represents $p < 0.05$, and *** represents $p < 0.01$.

Table 7 provides the estimated model and displays the value of coefficients and intercepts, and their corresponding standard errors. Based on the direction of the odds, positive and negative estimates represent predictors of higher and lower expectations, respectively. Values below the coefficients and standard errors are the coefficient parameters, which are converted to proportional odds ratios and their 95% confidence intervals. Brand test for each coefficient was included to test the assumption about proportional odds. The information fitted into this model shows that, overall, the model is significant ($p < 0.001$). Furthermore, we discuss the results in more detail. The results of the OLR analyses are summarized in Table 7.

The results show that three out of six independent variables have statistically significant relationships with the dependent variable. The variable gender appears to be the most influential factor (1.4384), where men tended to score lower on the dependent variable, with an odds ratio of 0.2373. In other words, for men in Saudi Arabia, the odds of being more likely (i.e., high or average benefits versus low benefits) to have positive expectations for the transition to higher utilization of AVs are 76.27% [i.e., $(1 - 0.2373) \times 100\%$]. This is lower than that for women, given that the other variables in the model are held constant. Results differ from other studies, which indicate that men are more likely to have positive attitudes towards AVs [23–26]. However, our results substantiate other studies, which find Saudi women are more likely to have positive attitudes towards AVs than Saudi men (see, for example, [31]). We conclude that this might be due to a higher inclination toward safety and the environment, but a more thorough examination is necessary.

The second most influential factor on people's opinions is their prior knowledge about AVs (1.1013), where people who have seen AVs before tended to score higher on the dependent variable with an odds ratio of 3.0081. The results showed that a total of 92.60% of participants in this survey had previously heard about or seen AVs, but these people were more likely to be in the middle age range (26–35) and have a higher degree of education. This represents a significant improvement over earlier research, which revealed that just 66% of participants in 2014 [28], 87% in 2016 [36], and 91% in 2020 [30] had previously heard about AVs. However, this result ties well with previous studies [25], wherein participants who had previously heard of autonomous or self-driving vehicles were more likely to expect a high level of benefits to be associated with the transition toward increased use of AVs. Consumer preferences of electric and automated vehicles are presented in [37].

Our results go beyond previous reports, showing that participants who had seen AVs before tended to be 3.01 times more likely to have positive expectations for the transition toward increased use of AVs than the people who had only heard or had never heard about AVs, holding all other variables constant. Therefore, increasing coverage of AVs in the Arab visual media will lead to higher public awareness of AVs. It is interesting to mention here that the same conclusion and suggestion were made by an acceptance divergence study conducted in the European Union (EU) [38]. Perspectives on autonomous cars were investigated among the media, citizens, and policy. We have shown that participants with prior knowledge on new technologies are more willing to accept them. This situation is the same as that in the EU. Apart from scientific sources, the role of the media is extremely important in this information dissemination process. Better worldwide understanding of new technologies is needed to raise awareness of their benefits, explain the risks, and speed up the acceptance process. We have already highlighted the importance of regulatory framework development. An interesting policymaking approach was proposed in an EU case study. Citizens could be engaged in and be a part of the policy development process. In so doing, they will be able to better understand the implications of the new AV technologies and the consequences in their daily life and mobility. This could be an approach in developing a new regulatory framework which would truly benefit community; however, this is not widely applicable. Communities around the world have different views on ethical, moral, and legal issues [39].

The third most influential factor is the public stakeholders group (0.8373), where people who belong to the public group tended to score higher on the dependent variable with the odds ratio 2.31. The results showed that people who belong to the industry stakeholders group are more likely to have positive expectations of the transition (29.35%). This is lower than people who belong to the government stakeholders group, holding constant all other variables. Note that the difference was not large enough to be statistically significant. Participants were also asked to self-identify their position in their organisation and this variable displayed a positive slope (0.1524). For a one unit (level) increase in management role, the odds of moving from a prediction of low benefits to average or high benefits were found to be 1.1646 times higher, with the other variables in the model held constant. On the calculation of the p-value, it was not large enough to provide evidence

($p > 0.05$) that the level of management role had an impact on people's opinions about the expected benefits that may accompany the transition toward increased use of AVs.

The age and education variables are not statistically significant, but they are still worth noting. Based on the parameter estimates shown in Table 6, those aged above 35 and those who had reached a higher level of education were found to be 1.7075 and 1.9080 times, respectively, more likely to have positive expectations for the transition toward increased use of AVs. Interestingly, our studies contradict to the findings of other studies, in that we did not find younger people to be more likely to have positive attitudes towards AVs than elderly people [40]. The results demonstrate that this is not necessarily true; however, it requires more detailed investigation.

A summary of all the responses to questions 17–31 is shown in Figure 10. The cumulative percentages for the two highest responses on the Linkert scale of 1–5, i.e., 0, 25, 50, 75, 100, are given in Figure 10. We can see that perceptions of safety, addressed in question 18, is the most important factor, accounting for 93% of the responses. Following safety are accuracy of driving, security in terms of anti-hacking measures, efficiency, comfort, health, privacy, and performance. The price of new technologies and the costs of using an AV are next on the scale. These factors are having a negative effect on peoples' decisions to accept these new technologies and invest in cars with higher levels of automation. Because we have a synergy of two transitions happening now, the transition to wider use of EVs and the transition to wider use of AVs, it is interesting to note that the costs of buying new EV is still higher, but the maintenance and usage costs are lower. Further developments in AV and EV technologies will bring them together and will drive prices and the usage costs down. Since we are conducting longitudinal surveys which repeat on regular bases, it will be interesting to see those two factors in future investigations. Sometimes, like in the EU, governments provide support, subsides, tax relief, etc., to buyers of new EVs [41], but not for new AVs. It is obvious that the use of EVs have a positive impact on the environment, bringing sustainable transport—if the energy used is green. Apart from support for customers to buy EVs, the Chinese government offer subsidies to manufacturers to encourage them to produce electrical vehicles [42]. The aim is to broaden the utilisation of sustainable transport and increase social welfare.

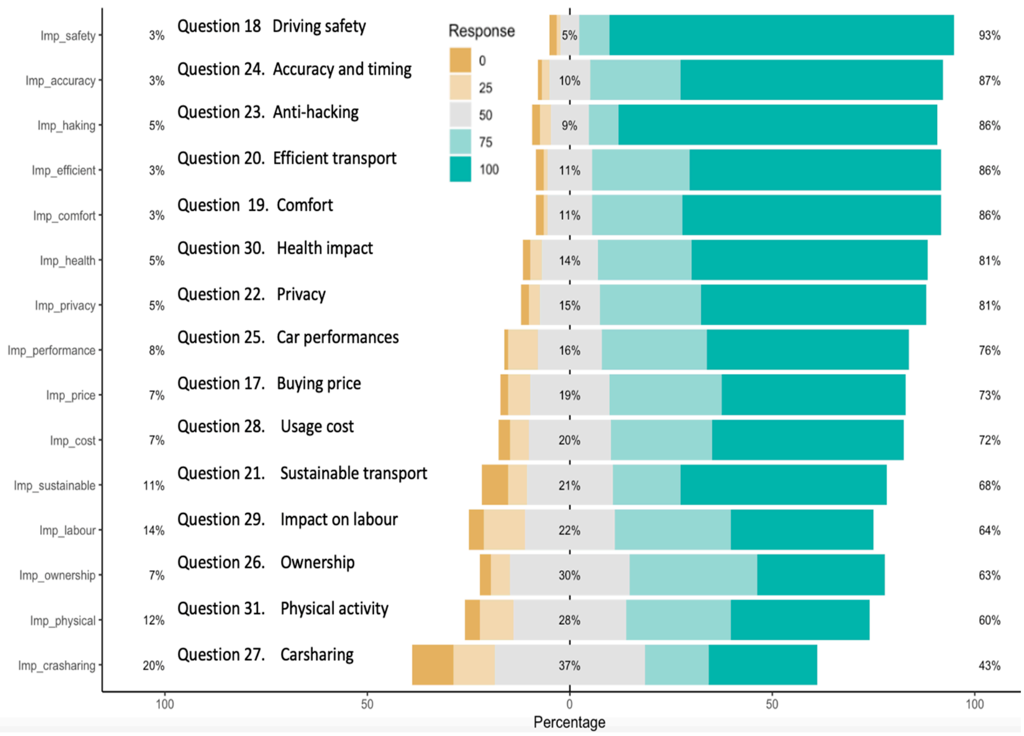

Figure 10. Responses to the questions from 17 to 31.

Contributions to sustainability are not as obvious in the case of AVs; this is the most likely explanation for sustainable transport, addressed by question 21, being further down on the list. Impacts on labour follows on the priority list. There might be job losses because of full automation, but the workforce restructure and retraining are needed to convert ICE employees to an EV labour force. The social impact of AV and EV transitions will be the subject of other investigations and surveys.

As the least important factors, we see ownership, lack of physical exercise, and car-sharing as the lowest priorities for new, future mobility options that will come with the transition to increased use of autonomous vehicles.

4.2. Qualitative Data Analysis

The dataset collected by our KSA survey is stored in RMIT University Qualtrics memory. As shown in Table 1, there are two open-ended questions. They were used for qualitative data collection. With question 14, we were enquiring about the expected benefits of switching to self-driving technology. Since we encouraged participants to present to us a minimum of two benefits, the total number of expected benefits is high, with a lot of overlap. Accordingly, we have identified the most frequent recuring responses to question 14; these are presented here:

- Safety: many respondents highlighted the potential for increased safety on the roads. They expect fewer accidents and a reduction in traffic violations, which they attributed to the advanced safety features and compliance with traffic rules that are inherent to AVs.
- Environmental benefits: another commonly mentioned benefit is the reduction in CO_2 emissions and environmental preservation. Respondents anticipate a positive impact on air quality and reduced pollution.
- Time efficiency: several respondents expressed expectations of time savings and increased efficiency in transportation. They believe AVs will allow multitasking during travel, performing job-related activities, and so reducing time wastage.
- Reduced congestion: respondents also associate AVs with reduced traffic congestion and more orderly road use, leading to improved traffic throughput and safety.
- Comfort and convenience: AVs are seen to offer comfort and convenience, especially for individuals with disabilities or those with limited driving skills. Respondents expect an easier and more relaxed travelling experience.
- Economic savings: some respondents highlighted potential cost savings, including reduced accident-related expenses and lower fuel consumption.
- Increased productivity: a few respondents mentioned the potential to increase productivity during travel, such as working or undertaking other business activities.
- Human error reduction: AVs are expected to minimize accidents resulting from human errors, such as driver fatigue or recklessness.
- Energy efficiency: respondents also foresee reduced energy consumption and cost savings due to the introduction of new technology.
- Traffic system improvement: some respondents believe that AVs will help enhance the overall traffic system and infrastructure.

In summary, the public's perspective on the benefits of transitioning to AVs emphasizes safety, environmental benefits, time efficiency, reduced congestion, comfort and convenience, economic savings, increased productivity, human error reduction, energy efficiency, and traffic system improvement. These anticipated advantages reflect widespread optimism regarding the potential positive impacts of AVs' introduction.

The next open-ended question was question 16. Here, we were enquiring about the expected risks of the transition to AV technology. Again, we received many responses that were overlapping. Following that, we have identified the most frequently recurring answers among all responses to this question. Here is the list of issues mentioned:

- System malfunctions: the most-mentioned risk is the potential for system malfunctions in AVs, with respondents expressing concerns about automatic control system failures, technical glitches, and the consequences of these malfunctions for road safety.
- Human complacency: respondents highlighted concerns about drivers becoming too reliant on AV technology, leading to a lack of activity and concentration in daily life. There are fears that over-reliance on AVs may result in drivers not paying attention to the road, which could be disastrous in the event of a system malfunction.
- Increased vehicle numbers: some respondents express concerns about the proliferation of AVs leading to increased congestion on the roads and higher energy prices.
- Hacking and cybersecurity: the possibility of cyberattacks on AVs is a recurring concern. Respondents are worried about the potential for the vehicle's system to be hacked, leading to loss of control or disruptions in driving.
- Safety and decision making: safety concerns extend to AVs making critical decisions when multiple factors are involved. There is a call for clear priorities and guidelines in such situations.
- Infrastructure and technical challenges: respondents mention worries about the readiness of road infrastructure to support AVs, the reliability of satellite communication in some areas, and overall infrastructure inefficiency.
- Moral and ethical risks: some respondents express concerns about the ethical implications of AV accidents, questioning who would bear responsibility in the event of an accident.
- Reduced human control: concerns are raised about AVs not being controlled by humans and the implications of this for safety and decision making.
- Vehicle and system failures: risks related to technical problems, software errors, and manufacturing defects in AVs are identified as potential hazards.
- Implications for employment: some respondents are worried about job losses due to the increased use of AVs and the reduction in the number of human drivers.

In summary, the public's perspective on the risks of transitioning to AVs highlights concerns about system malfunctions, human complacency, increased vehicle numbers, hacking and cybersecurity, safety and decision making by AI, infrastructure challenges, moral and ethical risks, reduced human control, vehicle and system failures, and potential job losses. These concerns reflect a wide array of considerations regarding the adoption of autonomous vehicles.

5. Conclusions

This paper presents the results of an investigation into the community's views on the transition to use of AVs in Saudi Arabia. The research was conducted at a time when AVs with a higher level of automation were relatively new to the KSA public and the market. A self-administered questionnaire was used to collect data on participants' awareness and knowledge of AVs, their attitudes towards AVs, and their readiness to use autonomous cars. The results of the descriptive analyses show that there is a difference between women and men in the expected benefits they reported for the transition to use of AVs. However, both groups reported that they predicted that there would be no high risk in the introduction of AVs on the roads of KSA. We can see that autonomous vehicles with higher levels of autonomy are well accepted in Saudi Arabia. Our investigation shows that people are willing to pay for automation, but only a small proportion reported that they would pay for fully automated vehicles at level 5. The timeline for the transition toward use of AVs is predicted to be 10 years in the survey responses. This is well aligned with the KSA government's strategy and planning for this important transition in the transport sector. At the same time, ITSs and smart cities are on the same timeline; these are directly correlated and interdependent.

The present findings confirmed the previously published outcomes in the literature, showing that Saudi women seem to favour AVs more than conventional vehicles. Results also showed that participants who had prior knowledge of AVs tended to have an attitude that was three times more positive towards the transition in comparison with people who had only heard or had never heard about AVs. This is the same finding that researchers have presented from conducting surveys in the EU, China, and other regions worldwide. There are concerns reported both in our study and globally present surrounding trust in the new technologies. It appears that, in addition to knowledge about a given new technology, trust in it is also built on existing relationship and trust with the manufacturers. This is common among drivers worldwide, but also among non-motorists and other road users. Further progress in AV technology and its introduction depends on the developments of more sophisticated AI algorithms. This constant improvement in AI is directly transferable and will influence AVs, intelligent transport systems, and smart cities.

The introduction of new technology will influence many sectors of human activities and businesses. Similar to any new industry revolution, workforce structure and requirements will change. In our survey, more than 50% of our participants expressed concern surrounding employment issues.

In conclusion, through increased safety, efficiency, and sustainability—in terms of lowering pollution—autonomous vehicles have the potential to revolutionise transport. AVs are a key modality among new mobility solutions and comprise a key subsystem in future ITSs. There are issues that need to be considered in terms of moral and ethical dilemmas with fully automated vehicles, as well as a regulatory framework for AVs. Progress is moving towards the development of comprehensive and reliable solutions for autonomous vehicles through utilising cutting-edge technologies, including big data analytics, IoT, ITS, AI, and cloud and edge computing. The whole ITS system, in the near future, will be supported by a more dependable and comfortable networking infrastructure thanks to the full application of ICT and VANET in handling the global transition to autonomous vehicles.

The limitation in our survey on the acceptance of new technologies in the automotive industry as presented here is that we have investigated only the transition to increased use of AVs and not the acceptance process surrounding electric vehicles. The AVs of the future will likely be electric vehicles, running on green electricity. Countries and regions around the world, like the EU, are introducing bans on the sale of new ICE vehicles, with relatively short timelines, like 2035. This indicates that we will see a smooth integration of AVs and EVs in the coming decade. Our investigation shows that the KSA community is ready for the AV transition by 2030, which is fully aligned with the government-planned Saudi Vision, 2030.

We plan to continue with our longitudinal surveys in the following years, both in KSA and globally. In addition to our qualitative and quantitative data collection, we will start with interviews and discussions with travel authorities and government representatives. Currently, two transitions are occurring—one to increased use of electrical vehicles and the other to increased use of autonomous vehicles; these transitions are occurring because ICEs are being phased out in many countries worldwide. This is a global process that requires a global management approach. Although it is global, public acceptance and timelines will be different. Trust in new technologies is based on trust in artificial intelligence and in the manufacturers that offer it. Governments play a key role in both of these transitions, and some have already made strategic, long-term decisions to invest and stimulate development. Saudi Arabia is one of them.

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References

1. Perallos, A.; Hernandez-Jayo, U.; Onieva, E.; García-Zuazola, I.J. *Intelligent Transport Systems: Technologies and Applications*; John Wiley: New York, NY, USA, 2015.
2. Todorovic, M.; Simic, M. Feasibility study on green transportation. *Energy Procedia* **2019**, *160*, 534–541. [CrossRef]
3. Corazza, M.V.; Carassiti, G. Investigating Maturity Requirements to Operate Mobility as a Service: The Rome Case. *Sustainability* **2021**, *13*, 8367. [CrossRef]
4. Ho, C.Q.; Hensher, D.A.; Reck, D.J.; Lorimer, S.; Lu, I. MaaS bundle design and implementation: Lessons from the Sydney MaaS trial. *Transp. Res. Part A Policy Pract.* **2021**, *149*, 339–376. [CrossRef]
5. National Highway Traffic Safety Administration. Preliminary Statement of Policy Concerning Automated Vehicles. Available online: https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/automated_vehicles_policy.pdf (accessed on 11 December 2023).
6. SAE Levels of Driving Automation™ Refined for Clarity and International Audience. Available online: https://www.sae.org/blog/sae-j3016-update (accessed on 20 September 2023).
7. Alsubaei, F.S. Reliability and Security Analysis of Artificial Intelligence-Based Self-Driving Technologies in Saudi Arabia: A Case Study of Openpilot. *J. Adv. Transp.* **2022**, *2022*, 2085225. [CrossRef]
8. Jain, A.; Bansal, R.; Kumar, A.; Singh, K. A comparative study of visual and auditory reaction times on the basis of gender and physical activity levels of medical first year students. *Int. J. Appl. Basic Med Res.* **2015**, *5*, 124. [CrossRef] [PubMed]
9. DinparastDjadid, A.; Lee, J.D.; Domeyer, J.; Schwarz, C.; Brown, T.L.; Gunaratne, P. Designing for the extremes: Modeling drivers' response time to take back control from automation using Bayesian quantile regression. *Hum. Factors* **2021**, *63*, 519–530. [CrossRef] [PubMed]
10. Elbanhawi, M.; Simic, M. Sampling-Based Robot Motion Planning: A Review. *IEEE Access* **2014**, *2*, 56–77. [CrossRef]
11. Elbanhawi, M.; Simic, M.; Jazar, R. In the Passenger Seat: Investigating Ride Comfort Measures in Autonomous Cars. *IEEE Intell. Transp. Syst. Mag.* **2015**, *7*, 4–17. [CrossRef]
12. Salameh, T.; Sayed, E.T.; Abdelkareem, M.A.; Olabi, A.G.; Rezk, H. Optimal selection and management of hybrid renewable energy System: Neom city as a case study. *Energy Convers. Manag.* **2021**, *244*, 114434. [CrossRef]
13. Dasari, H.P.; Desamsetti, S.; Langodan, S.; Karumuri, R.K.; Singh, S.; Hoteit, I. Atmospheric conditions and air quality assessment over NEOM, kingdom of Saudi Arabia. *Atmos. Environ.* **2020**, *230*, 117489. [CrossRef]
14. Aldakkhelallah, A.; Simic, M. Autonomous Vehicles in Intelligent Transportation Systems. In *Human Centred Intelligent Systems*; Zimmermann, A., Howlett, R.J., Jain, L.C., Schmidt, R., Eds.; Springer: Singapore, 2021; pp. 185–198.
15. Sharma, R.; Ahmad, N.; Ali, S.; Bilal, A.; Fatima, S.; Kshetri, N.; Salem, F.A.; Sibal, P. Technomoral Affordances of Artificial Intelligence in Data-Driven Systems. *Computer* **2022**, *55*, 76–81. [CrossRef]
16. Zhang, T.; Tao, D.; Qu, X.; Zhang, X.; Zeng, J.; Zhu, H.; Zhu, H. Automated vehicle acceptance in China: Social influence and initial trust are key determinants. *Transp. Res. Part C Emerg. Technol.* **2020**, *112*, 220–233. [CrossRef]
17. Tennant, C.; Howard, S.; Franks, B.; Bauer, M.W.; Stares, S. Autonomous Vehicles-Negotiating a Place on the Road: A Study on how Drivers Feel about Interacting with Autonomous Vehicles on the Road (Executive Summary). 2016. Available online: https://www.lse.ac.uk/business/consulting/assets/documents/autonomous-vehicles-executive-summary.pdf (accessed on 11 December 2023).
18. Bekiaris, E.; Petica, S.; Brookhuis, K. Driver needs and public acceptance regarding telematic in-vehicle emergency control aids. In Proceedings of the Mobility for Everyone. 4th World Congress on Intelligent Transport Systems, Berlin, Germany, 21–24 October 1997; Paper No. 2077.
19. Newcomb, D. You Won't Need a Driver's License by 2040. 2012. Available online: https://www.wired.com/2012/09/ieee-autonomous-2040/ (accessed on 11 December 2023).
20. Deb, S.; Strawderman, L.; Carruth, D.W.; DuBien, J.; Smith, B.; Garrison, T.M. Development and validation of a questionnaire to assess pedestrian receptivity toward fully autonomous vehicles. *Transp. Res. Part C Emerg. Technol.* **2017**, *84*, 178–195. [CrossRef]
21. Qu, W.; Xu, J.; Ge, Y.; Sun, X.; Zhang, K. Development and validation of a questionnaire to assess public receptivity toward autonomous vehicles and its relation with the traffic safety climate in China. *Accid. Anal. Prev.* **2019**, *128*, 78–86. [CrossRef] [PubMed]

22. Aldakkhelallah, A.; Todorovic, M.; Simic, M. Investigation in Introduction of Autonomous Vehicles. *Int. J. Adv. Electron. Comput. Sci.* **2021**, *8*, 6. Available online: http://ijaecs.iraj.in/paper_detail.php?paper_id=18207&name=Investigation_in_Introduction_of_Autonomous_Vehicles (accessed on 11 December 2023).
23. Rice, S.; Winter, S.R. Do gender and age affect willingness to ride in driverless vehicles: If so, then why? *Technol. Soc.* **2019**, *58*, 101145. [CrossRef]
24. Golbabaei, F.; Yigitcanlar, T.; Paz, A.; Bunker, J. Individual predictors of autonomous vehicle public acceptance and intention to use: A systematic review of the literature. *J. Open Innov. Technol. Mark. Complex.* **2020**, *6*, 106. [CrossRef]
25. Huang, Y.; Qian, L. Understanding the potential adoption of autonomous vehicles in China: The perspective of behavioral reasoning theory. *Psychol. Mark.* **2021**, *38*, 669–690. [CrossRef]
26. Othman, K. Public acceptance and perception of autonomous vehicles: A comprehensive review. *AI Ethics* **2021**, *1*, 355–387. [CrossRef]
27. Saudi Arabia (KSA) Population Statistics. Infographics. Available online: https://www.globalmediainsight.com/blog/saudi-arabia-population-statistics/#:~:text=Saudi%20Population%20by%20Age%20The%20age-wise%20population%20of,million%20i.e.,%2051.86%25%20people%20in%20this%20age%20group (accessed on 5 December 2022).
28. Schoettle, B.; Sivak, M. *A Survey of Public Opinion about Autonomous and Self-Driving Vehicles in the US, the UK, and Australia*; University of Michigan, Ann Arbor, Transportation Research Institute: Ann Arbor, MI, USA, 2014.
29. Howard, D.; Dai, D. Public perceptions of self-driving cars: The case of Berkeley, California. In *Transportation Research Board 93rd Annual Meeting*; The National Academies of Sciences, Engineering, and Medicine: Washington, DC, USA, 2014; Volume 14, pp. 1–16.
30. Thomas, E.; McCrudden, C.; Wharton, Z.; Behera, A. Perception of autonomous vehicles by the modern society: A survey. *IET Intell. Transp. Syst.* **2020**, *14*, 1228–1239. [CrossRef]
31. Alsghan, I.; Gazder, U.; Assi, K.; Hakem, G.H.; Sulail, M.A.; Alsuhaibani, O.A. The determinants of consumer acceptance of autonomous vehicles: A case study in Riyadh, Saudi Arabia. *Int. J. Hum. Comput. Interact.* **2022**, *38*, 1375–1387. [CrossRef]
32. Nihal, M. Saudi Arabia: Women in Work Has 'Doubled' to over 35 Percent of Labour Force. *The National*, 18 May 2022. Available online: https://www.thenationalnews.com/gulf-news/saudi-arabia/2022/05/18/saudi-arabia-women-in-work-has-doubled-to-over-35-of-labour-force/#:~:text=Saudi%20Arabia:%20Women%20in%20work%20has%20%E2%80%98doubled%E2%80%99,to%20over%2035%25%20of%20labour%20force%20Home%20UAE(accessed on 5 December 2022).
33. Hosmer, D.W., Jr.; Lemeshow, S.; Sturdivant, R.X. *Applied Logistic Regression*; John Wiley & Sons: Hoboken, NJ, USA, 2013.
34. Osborne, J.W. *Best Practices in Logistic Regression*; Sage Publications: Thousand Oaks, CA, USA, 2014.
35. Du, H.; Zhu, G.; Zheng, J. Why travelers trust and accept self-driving cars: An empirical study. *Travel Behav. Soc.* **2021**, *22*, 1–9. [CrossRef]
36. Piao, J.; McDonald, M.; Hounsell, N.; Graindorge, M.; Graindorge, T.; Malhene, N. Public views towards implementation of automated vehicles in urban areas. *Transp. Res. Procedia* **2016**, *14*, 2168–2177. [CrossRef]
37. Shabanpour, R.; Mousavi, S.N.D.; Golshani, N.; Auld, J.; Mohammadian, A. Consumer preferences of electric and automated vehicles. In Proceedings of the 2017 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS), Naples, Italy, 26–28 June 2017; pp. 716–720. [CrossRef]
38. Dos Santos, F.L.M.; Duboz, A.; Grosso, M.; Raposo, M.A.; Krause, J.; Mourtzouchou, A.; Balahur, A.; Ciuffo, B. An acceptance divergence? Media, citizens and policy perspectives on autonomous cars in the European Union. *Transp. Res. Part A Policy Pract.* **2022**, *158*, 224–238. [CrossRef] [PubMed]
39. Maxmen, A. Self-driving car dilemmas reveal that moral choices are not universal. *Nature* **2018**, *562*, 469. [CrossRef] [PubMed]
40. Golbabaei, F.; Yigitcanlar, T.; Bunker, J. The role of shared autonomous vehicle systems in delivering smart urban mobility: A systematic review of the literature. *Int. J. Sustain. Transp.* **2021**, *15*, 731–748. [CrossRef]
41. Ministry of Infrastructure and Water Management. Apply for a Subsidy to Buy or Lease an Electric Car. 2022. Available online: https://www.government.nl/topics/vehicles/apply-for-a-subsidy-to-buy-or-lease-an-electric-car (accessed on 11 December 2023).
42. Zheng, X.; Lin, H.; Liu, Z.; Li, D.; Llopis-Albert, C.; Zeng, S. Manufacturing Decisions and Government Subsidies for Electric Vehicles in China: A Maximal Social Welfare Perspective. *Sustainability* **2018**, *10*, 672. [CrossRef]