Case Report

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Case Report

Public Perception on the Introduction of Autonomous Vehicles

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Abstract: Autonomous vehicles (AV)s will transform transport, but public opinion will play a key role in the decision how widely and quickly, they will be adopted. The purpose of the study presented here, was to investigate community's views on the 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 have used statistical tools to analyse responses. Our findings indicate that the participants are mainly open to use new technology and had favourable attitude towards transition. Ordinal logistic regression model showed a wide variation in public opinion regarding the expected benefits that may accompany the transition, despite an average high score on this factor. Our findings reveal that awareness of AVs' benefits is more positively correlated to the age of participants. Perceived cost, on one side, and convenience, and safety, on the other side, have substantial impact on opinions. Investigation, presented here, shows how AVs are seen in Saudi Arabia. This can guide the development of AVs and deployment in that region.

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

1. Introduction

Autonomous and electrical vehicles are transforming transport sector. We are in transition from personally owned means of transport towards mobility as a service (MaaS) platform. Thanks to AVs we will have more efficient transport, and so less pollution, with better safety. Electric cars make it feasible to have green transport, if the electricity is green [1]. EVs are reducing greenhouse gases emissions coming from internal combustion engines (ICE)s. Thanks to MaaS we will have smaller number of vehicles on the road and the same benefits introduced by AVs. However, 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 [2].

Information and communications technology (ICT) supports vehicles through connectivity and networking system known as vehicular ad hoc network (VANET) [3]. AVs and VANET are subsystems in intelligent transport system (ITS). ITS is monitoring traffic using Internet of Things (IoT) and will soon control it using Artificial Intelligence (AI). We are already conducting research in technology, and in management of transitions to autonomous, electrical vehicles and ITS [1,2,4–8]. EVs now have few hybrid technologies while AVs are categorized in 5, according to National Highway Traffic Safety Administration [9], or in 6 levels of autonomy, as per Society of Automotive Engineers (SAE) [10] taxonomy.

According to 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 focussed 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. 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 during 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 automotive sector must respond with new business models. Because those AV and EV transitions are global, we have applied hard systems approach (HAS), and soft system approaches (SSA) 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 are still being improved, but it is ongoing process. Finally, not everyone will go for full autonomy. At the lower levels, 1 and 2, driver warning and many other applications for active safety are already in place and there are no issues. Issues come at the highest levels 4 and 5, i.e., with full automation. AVs on that level are mobile robots on the road. There are many applications for autonomous systems, including those in manufacturing, agriculture [11], transport [2,6,7,12–15], and the defence [16].

Figure 1a shows an electrical vehicle designed by RMIT University students, while Figure 1b show RMIT autonomous vehicle. For a commercially available electrical vehicle, AV software was developed, and MATLAB program was running on a laptop, siting on the driver sit, replacing driver. LiDAR was used to create mapping of the environment.

(**a**) (**b**)

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

Applying HSA we have concluded that the technology is ready for the transition. 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 sued in dealing with 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 AV and non-AVs on the road, we have to deal with ethical and moral issues, and we need regulatory framework to approve application of those intelligent systems.

In any system, all stakeholders are involved in making decisions. They have different views of the systems and ways to solve problems and go forward. With SSA, we are managing the transition to autonomous vehicles by working with all parties, including the government, traffic authority, public and manufacturing companies. The introduction of autonomous vehicles has raised concerns about user safety, costs, reliability, sustainability [7] and ride comfort [12]. We use the soft systems approach, because it is a method for comprehending and undertaking difficult issues with a lack of clear solutions and agreements. SSA approach is defined by a focus on comprehending the dynamic and complex nature of real-world problems. It is developing workable solutions that consider the requirements and viewpoints of all stakeholders. 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,

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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 element. Relationships between various components are represented using 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, SSA approach is especially well suited to the management of the autonomous cars' introduction. Following that, we have conducted longitudinal surveys which included participants from all stakeholders' groups.

AVs are subsystems in ITS, which are subsystems in smart cities. Smart cities are metropolitan areas that use cutting-edge technology to enhance citizen quality of life and economic growth. They use Internet of Things (IoT), that generate big data, use 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 [17,18]. The 26,500 square mile metropolis of NEOM is being built to be a global hub for cutting-edge technologies [8]. Autonomous vehicles will be used for transport services and to link the city to the surrounding areas. Deployment of autonomous vehicles in NEOM is anticipated to provide a number of advantages, including greater mobility for citizens, increased safety, and decreased congestion and pollution.

We have already presented technology acceptance model for autonomous vehicles [19]. AV technology is ready for deployment when the following four stages are completed: Engineering, Legal, Moral and Ethical. They are shown in Figure 2. Engineering stage has bidirectional links, because we have feedback involved in the constant engineering improvements, based on regular evaluations, technology progress and changes in customer requirements.

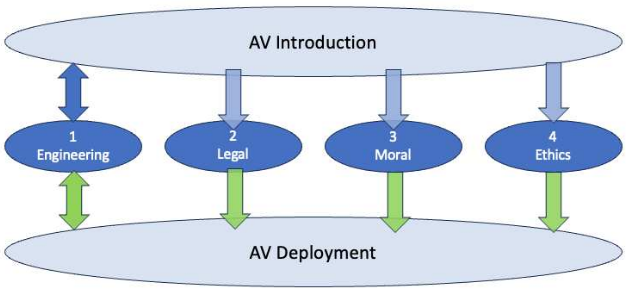

Figure 2. Stages in AV technology deployment.

Autonomous vehicle, at all levels of autonomy, play significant role in the development of modern transport systems [20]. Clarifying issues, especially from stages 3 and 4, as shown in Figure 2, is the most significant obstacle to AV adoption, not the technical aspect [21]. 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 a huge concern among drivers about self-driving vehicles and many of them are hesitant to use them [22], however, drivers welcomed active safety through driver warning systems [23]. Therefore, the basic benefit of AVs, such as increased safety and fuel efficiency may not be enough to make drivers hand over control to automated cars [24]. We believe that increase public awareness of AVs may contribute to promote this technology and advance its adoption.

While some efforts have been made to either understand why people would use AVs or to what extend social and personal factors may influence the acceptance of AVs, few of them have measured the extend of familiarity with AVs. The community's attitudes and readiness to purchase, which can differ by country, have an impact on when and how autonomous technology will be adopted. Presented study aimed to fill in this research gap and obtain better view of typical members of major stakeholder groups, i.e., industry, government, traffic authorities and general public. This enables us to investigate public awareness of AVs and to measure diverse consumer readiness for the transition to new technology in Saudi Arabia. As we found, there is a lack of studies on public opinion about autonomous vehicles in the Middle East.

2. Materials and Methods

We are conducting two longitudinal surveys concurrently. Questionnaire is a primary research method used to identify public perception about AVs due to its ability to gain in-depth opinions [25,26]. In 2022, two surveys were conducted on the topic of AVs introduction, one in Saudi Arabia and the other one in Australia. They are a follow-up to the Saudi Arabia-based survey from 2021. The purpose of these studies is to collect primary data and compare survey results from one country to another, glean an insight into the opinion of people in the acceptance of AV technology based on various countries and the time interval between the two questionnaires. We are planning to conduct multi-year longitudinal studies. Results will be utilized to assist legislations preparation, technology development, and increase public awareness. Throughout this section, we outline the survey instructions and questionnaire content, justification, participants, limitations, validity and model selection.

A self-administered questionnaire, with 31-item questions, was designed to collect de-identified data. Responses were collected through a secure survey design program Qualtrics. Investigation was approved by the RMIT University Ethics Committee (#23507). All recommended best practices for executing the survey were followed. KSA survey was in Arabic, and all mandatory instructions were translated into Arabic. In the pamphlet, we have explained the purpose of the survey and remind respondents that participation is voluntary, and that their comments will 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. The survey would end if the participant was underage (younger than 18 years of age) or did not drive before. It is mentioned to the participants that the survey would take about 7 to 10 minutes. Contact details of the principal investigator were given for any enquiries. Survey starts when participant's consent is obtained. They were free to withdraw at any time. We wanted to measure familiarity with AVs, expected benefits, and concerns of adopting autonomous technology.

The questionnaire has four sections. Demographic data were collected in the first section, such as gender, age, educational levels, stakeholder groups, and current mode of transport. The next set of questions is aimed at assessing the depth of the respondents' familiarity with the AVs. Afterwards, a set of questions are focused on the expectation about AVs, car ownership in the future, level of automation that they are willing to buy, time to buy and timeframe for the transitions in Saudi Arabia. The third section cover anticipated benefits and risks from the transition into autonomous technology.

In the last 15 questions, survey proceed with enquiries about importance of AV- specific functionality, such as importance of safety, comfort, performances, and system security. The use of quantitative data is the principal focus of the questionnaire and is collected through multiple-choice questions. The participants were only asked two overarching questions where qualitative data could be used to answer these questions to write about their opinions on benefits and risks people might face from AV transition: "Please list the benefits you can predict from this transition" and "Please list the risks you can predict from this transition". However, participants might offer a small and inconsistent amount of information which would be difficult to model since only a few insights can be included. Therefore, participants are questioned about their feelings on specific benefits, or concerns, to ensure that a consistent amount of data is acquired from each participant. These data were used in the model to predict user awareness of the benefits and risks of the transition into this technology.

All Questions are given here:

1. What is your gender?
2. Which age group do you belong to?
3. What is your highest education level?
4. Your current mode of transport?

5. Which of the key stakeholders' groups do you belong to?
6. What is your management role in your organisation?
7. Have you heard about or seen an autonomous vehicle?
8. How do you see car ownership in the future?
9. What is your preferred level of automation?
10. Which of the following levels of autonomous vehicles you are willing to pay for?
11. When do you plan to buy an autonomous vehicle?
12. When do you see transition to autonomous vehicles will happen?
13. To what extent do you see benefits from the transition to autonomous vehicles?
14. Please list the benefits you can predict from this transition:
15. Do you see risk from autonomous vehicles transition?
16. Please list the risks you can predict from this transition:
17. Out of all attributes of autonomous vehicles how important is the price on the scale 0 (not important) to 100 (the most important):
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):
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):
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):
21. Out of all attributes of autonomous vehicle how important is the more sustainable transport, i.e., less pollution, less CO2 and less global warming, thanks to new technology, on the scale 0 (not important) to 100 (the most important):
22. Out of all attributes of autonomous vehicles how important is the privacy on the scale 0 (not important) to 100 (the most important):
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):
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):
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):
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):
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):
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):
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):
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):
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):

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 awareness of AVs. One of the hypotheses is that those who have better educated and are aware of the benefits, and all other aspects of driverless transport, could have more interest

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in buying an AV with higher level of automation, sooner, than those who have less educated and see high risks from the transition into AV technologies.

In terms of the grouping strategy, the categories used for user demographics such as gender, age, and education level were designed based on previous studies in the field [19]. The inclusion of these variables tests whether there are any differences between categories towards the adoption of AVs. For example, previous studies found that age and gender might have effects on consumers' willingness to ride in driverless vehicles, such as those who are male and younger are more likely to have positive attitudes towards AVs [27–30].

In addition, the survey has included two clustering questions that specify the typical members of major stakeholder groups and their level of management role in their organisation. This provides a better quality of findings by classifying them according to specific groupings that enables us to determine the causal relationship between the public awareness of AVs and various stakeholder groups.

Further to this, prior knowledge of AV was examined, as participants were asked whether they have ever heard about or seen an autonomous vehicle before participating in this survey. By doing this, it allows us to justify their perception of AV. For example, those who have seen AV have different biases from those who only just heard about AV, and subsequently to those who do not ever hear about or seen AV at all. These three distinct categories are helpful in categorising responses into groups to present their varied perception of AV based on their prior knowledge accurately. Comparisons are discussed in the evaluation and analysis process.

In terms of customer opinions and preferences, we asked about the willingness to buy a vehicle with AV technology and time of planning to buy, as well as their expectation for car ownership in the future and time horizon of its introduction in Saudi Arabia. The output of these questions can be used as a users' feedback pointer to technology designers and regulators to harmonize their product in line with customer preferences, such as anticipating the time to buy and to what level of automation the community is willing to buy.

The questionnaire was distributed online to residents in Saudi Arabia and was accessible online for two weeks starting on June 20th , 2022 and closing on July 3rd 2022. During this period, a total of 108 surveys are considered as valid, with respondents aged 18 and over. Of this sample, 17.6% are female and 82.4% are male, with 0% are selected 'prefer not to say'. Table 1 presents 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 a binary gender difference, as seen in Table 1. The results showed a range of credentials in terms of their age, level of education and current management role. The respondents' age is ranged from 18 to over 55 years and most of the participants belonged to the young-age group, 40.75% from ages 26-35 years old (compared with 19.25% nationally [31]). Younger age group, ages 18-25 years old, represent 22.22% of the sample (compared with 13% nationally [31]), while middle-age group represented 36.11% of the sample (compared with 32.9% nationally [31]).

In our survey, more than half of the participants (>52%) have higher qualification of master's degree or higher (Postgraduate Degree) and is different from the existing studies [32,33] and higher than recent studies [34,35]. The survey has also involved a question about the current mode of transport to the respondents in which 96.3% of the respondents are car owners and the rest 3.7% use public transport. There was no specific target group for the questionnaire and respondents came from three major stakeholder groups, which are industry (12.4%), government (59%) and general public (28.6%).

The respondents' management role is recorded using a scoring system of the highest level of leadership/management to no management levels at all (5-level of choices where (i) Level 5 'Highest' =29.5%, (ii) level 4 = 21%, (iii) level 3 = 12.4%, (iv) level 2 =9.5%, (v) level 1 =11.4% and (vi) level 0 'No management levels' = 16.2%). Note that females only scored less than the males on the average age, ($t = -2.9883$, $p=0.006$), and level of management role, ($t = -2.4485$, $p = 0.022$). This is due to the subsequent 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

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males have dominated this sector for decades and the participation of women just has been effectively activated in the past few years (since 2018), but still not reached the level of equality between the genders. According to the National news [36], Saudi women represent approximately 35 percent of the Saudi workforce.

There were some constraints on the participant segments and the collected data due to the nature of questionnaire use. The first constraint is that most of the participants were male, 82.4% (compared to 57.76% nationally [31]), most likely is due to the same reason mentioned above, i.e., in Saudi Arabia, women were only allowed to drive a few years ago before the survey was conducted and thus there are fewer women drivers to be included. Despite the fact that the difference in the genders' sizes does not generates any bias, this limits the representation of one gender. However, the percentage of female participants in this study is higher than in recent studies (see for example [35]). As another constraint, only one response is recorded over 55 years of age, most likely because the study was distributed over social networking websites and online automotive groups where, in Saudi Arabia, this age group is hard to be found in there. However, most of the participants belonged to ages in the interval (25, 55) years representing 76.7% of the sample (compared with 51.86% in population nationally [31]).

Table 1. 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	**-2.9883 [0.006**] (-0.950408, -0.175553)**		
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	**-1.0463 [0.304] (-0.573022, 0.185086)**		
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	**1.1182 [0.277] (-0.071780, 0.237363)**		
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)

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T-test	**1.4048 [0.173]** **(-0.186977, 0.986504)**		
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	**-2.4485 [0.022*]** **(-2.151645, -0.185433)**		

According to the population of Saudi Arabia by age groups, the majority of people are between the ages of 25 and less than 55 [31]. Therefore, it could be the most important group to be studied to measure their adaption and interest to drive a vehicle with AV technologies in the coming years. This should not be considered as a constraint when drawing conclusions from the survey data. To overcome this issue, we have merged the two age groups of '36-55' and 'above 55' and hereinafter they will be under one group called 'above 35'.

A constraint that should be considered is that no responses have been recorded from the traffic authorities as they are one of four major stakeholder groups. It could be a security restriction that this group is not allowed to participate in any survey without permission from higher authorities. In Saudi Arabia, however, people who work for traffic authorities are actually working under government regulations. Thus, given almost 60% of responses were recorded by the government group, this percentage could be used to represent both groups. Another constraint in representation is that no responses have been recorded from drivers with education level of primary school. Most likely this is because the Kingdom of Saudi Arabia requires citizens to attend school and gives grants for those who study higher education.

Another constraint is that, in the transport mode section 96.3% of the respondents are car owners. That does not represent well the people using public transport. This could be due to the limited options available for users since moving around in Saudi Arabia often requires a car. It should be no surprise that taxicabs are prevalent in the Kingdom. The transport by rail in Saudi Arabia is a fairly new option, and only exists in some parts of the country as link between cities. This will not cause bias, but it does limit the representation to one transport mode.

Although there are some limitations associated with the selection of participants, our study has gathered responses from users with diverse levels of management roles in industry, government, and public. This provides a wide-ranging view of the perceptions on implementing and preparing for the transition to the new AV technology. It enables us to establish whether there are differences between the major stakeholders' groups. This can help us to conclude if the government, along with the community, businesses, and industry, in Saudi Arabia, are ready for the adoption of AV technologies. Additionally, more than 90% of participants have at least heard about autonomous, or self-driving vehicles, before participating in this survey (see Figure 3). Responses from users who have prior knowledge of the existence of AVs promote the validity of the study, as their responses to the questions given on the opinions and preferences of AV were answered with better knowledge. 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 of respondents' categories and demographics (see Table 1).

The fact that this survey was conducted in Saudi Arabia means that it does not represent a global perception, but it does allow for comparison 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

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world, as mentioned in the introduction. The sample of survey participants is sufficiently diverse to reliably represent the general population. Therefore, we anticipate that our investigation is a contribution to the general research on this emerging technology.

2.1. Model approach

An ordinal logistic regression (OLR) was applied to examine the significant factors that could help understand level of awareness using the perceived *benefits* of this transition as a dependent variable. The OLR method is a widely used classification method. 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. Second, the OLR method does not need to assume equal intervals between scoring categories, unlike other regression models. Third, the OLR method takes account of 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 somehow complicated. It is considered as one of the most admired methods in the field of data analytics.

Before we fit an ordinal logistic model, we must decide what outcomes to compare and what the most reasonable model is for the *logit*. In our case, we would like to compare the lower probability with higher probability of public awareness of AVs. Therefore, the proportional *odds* model will be suitable to apply due to the reason of the subsequent attractive peculiarities: (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 the 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 as well as the intercept have different interpretations in OLR model. Unlike simple linear regression, in OLR model we obtain (*n-1*) intercepts, where *n* 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 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 be the categorical outcome with J ordered categories for lth subject with p independent variables. The *log odds*, also known as the *logit*, is given as follows:

$$logit\ [Y_l \ \leq j|x_l]] = \log\left[\frac{\pi_j(X_l)}{1-\ \pi_j(X_l)}\right] \tag{1}$$

$$logit\ [Y_l \ \leq j|x_l]] \ = \ \alpha_j - \beta_1 x_{1l} - \cdots - \beta_p x_{pl} \tag{2}$$

$$logit\ [Y_l \ \leq j|x_l]] = \ \alpha_j - X_l^{/}\beta \ \ for\ j = \ 1, 2, 3, \ldots, J-1;\ l = 1,2, \ldots, n \tag{3}$$

Where $\pi_j(X_l) = \Pr[Y_l \ \leq j|x_l]$, $X_l = (x_{1l}, x_{2l}, \ldots, x_{pl})$, β is a column vector of p coefficient of the regression, and α_j is the ith intercept. For more details on ordinal logistic regression, see textbooks on logistic regression models (e.g. [37,38]). The following evaluation, various plots and analysis depict the distribution of results for most of these questions.

3. Results

A total of 115 participants completed the survey, 15 of whom added further commentary about the study or suggested changes that might be made if it were to be distributed again, while approximately 75 of them listed their expectation about the benefits and risks we might face from this transition. After inspecting the data, 7 responses were removed due to incomplete answers resulting in the final sample of 108 responses. Although 7 data were deleted, however the remaining sample size of 108 is sufficient enough to perform the analysis.

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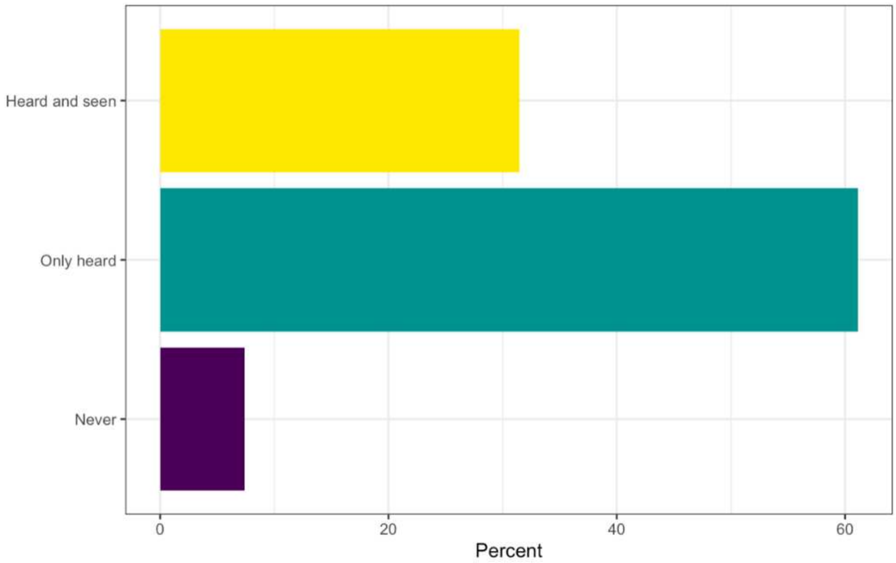

Figure 3. Percentage of people with the prior knowledge of the existence of AVs.

Participants' responses to the question related to prior knowledge of AV 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 AV as seen earlier [32]. Therefore, these two factors can be compared to the initial question of the participant's prior knowledge of AV.

Figure 4 shows the age groups of the participant compared to their prior knowledge of the term 'autonomous vehicle'. The age group of Above 35 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 at least heard, 18–25 years, having approximately 20% respondents compared to around 39% respondents of 26–35-year-old who had heard about and/or seen AVs. It is worth noting that the 26–35 age group has the highest subset who have seen AVs in real life. Additionally, the initial question of the participants' prior knowledge of AV can be also compared to the highest level of education. As shown in the Figure 5, there is a clear correlation between the level of education and awareness of AV technology.

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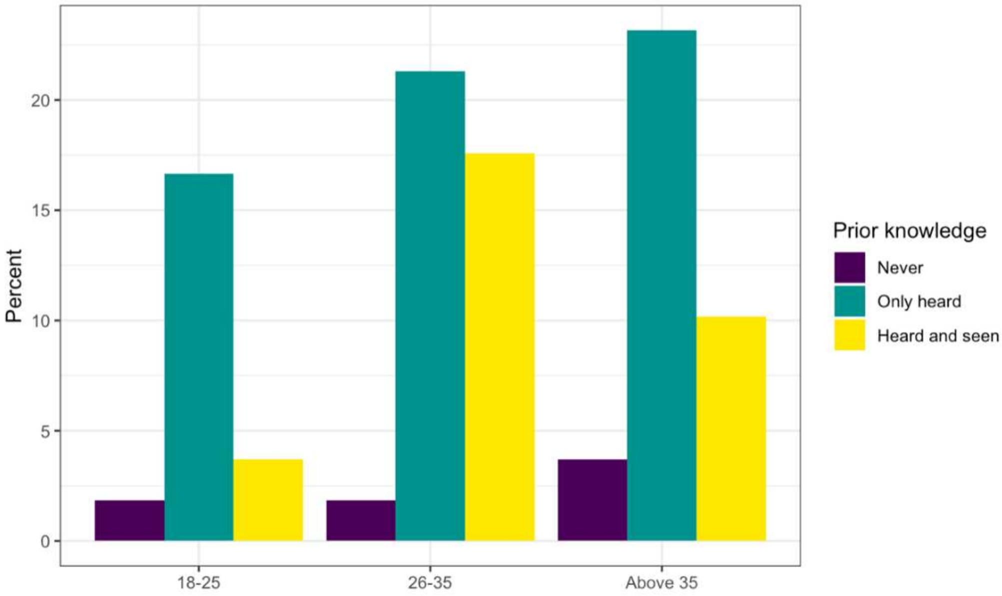

Figure 4. Comparison of age group and prior knowledge of AVs.

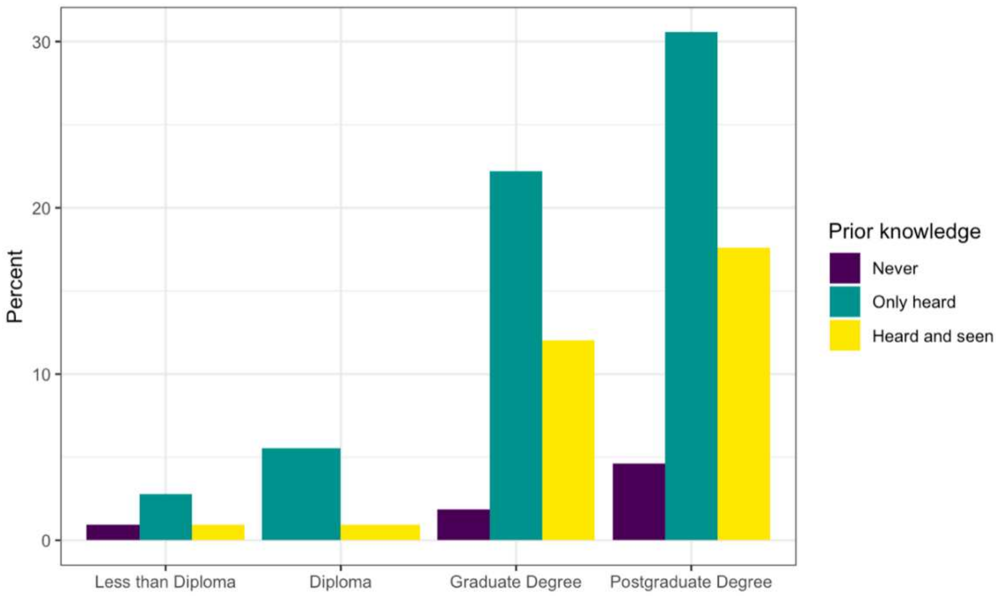

Figure 5. Comparison of education level and prior knowledge of AVs.

Two further questions were asked to gauge the respondents' interest regarding the preferred level of autonomy. Table 2 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 2, the majority of respondents were more interested in having automated driving system on their vehicles but less likely to buy a fully automated vehicle at level 5. Respondents most frequently had chosen to buy partially automated vehicle at level 4 (36.11 %), followed by partially automated vehicle at level 3 (24.07 %). One-tailed t-test also showed that the acceptance of AVs is extremely significantly higher than level 2 to the preferred level and willingness to buy, p-value = $1.56\, e^{-12}$and $9.9\, e^{-11}$, respectively. In line with previous questions, respondents were asked to tell when they plan to buy AVs and give their opinions on the timeline for the transition to the AV technology in KSA. Half of the respondents (50%) are planning to buy an AV in 10 years, whereas more than 40% are indicating a 2030 as a transition year for AVs, as shown on Figure 6.

Expectedly, the year 2030, is aligned with the SA government's long-term planning for the introduction of intelligent transport and smart cities.

Table 2. The level of AV acceptance data.

Level of AV	Preferred Level $\mu_0 \leq Level\ 2,\ \mu_1 > Level\ 2$ T-test, P-value = 1.56e-12	Willing to pay $\mu_0 \leq Level\ 2,\ \mu_1 > Level\ 2$ T-test, P-value = 9.9e-11
Non-automated vehicle, level 0	9.26 %	7.41 %
Partially automated vehicle, level 1	8.33 %	9.26 %
Partially automated vehicle, level 2	12.04 %	16.67 %
Partially automated vehicle, level 3	20.37 %	24.07 %
Partially automated vehicle, level 4	20.37 %	36.11 %
Fully automated vehicle, level 5	29.63 %	6.48 %

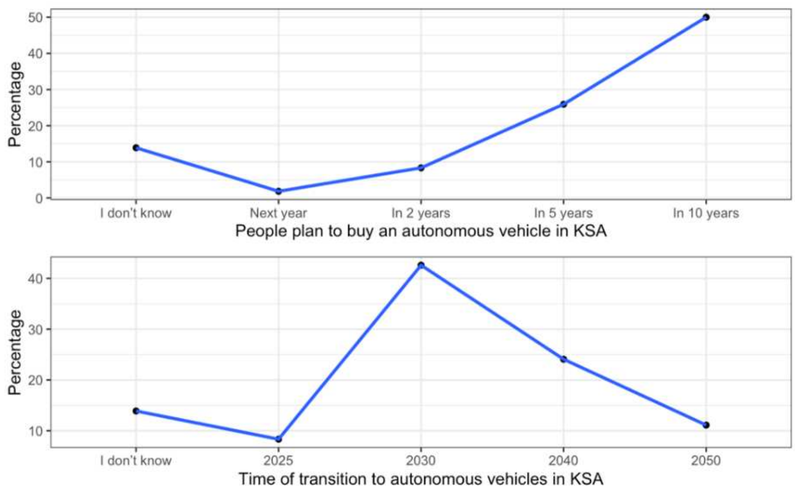

Figure 6. Percentage of responses to Q11 and Q12, i.e., timeline to buy an AV.

Participants were asked questions about benefits and risks from the transition to AVs. Based on Table 3, most had a positive attitude. When collapsed summaries (high responses versus low responses) were calculated, 51.86% of respondents answered that there would be a high benefit associated with the transition to AVs. Total of 48.15% answered that there would be only a low risk from the transition. There were very close percentages of respondents who answered with average benefits and risks that may accompany the transition to AVs, 34.26% and 39.81%, respectively.

Table 3. 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 %

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Comparatively, previous research, [27–30], found that gender might have effects on consumers' perceptions. Thus, we include two 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 from both females and males who are more likely to have positive attitudes toward AVs. However, a between-groups t-test showed that significantly more females would expect benefits from this transition than males, ($t = 2.0629$, $p = 0.04817$), whereas only slightly more females than males would expect fewer risks ($t = -1.9295$, $p = 0.06239$), but the difference was large enough to be statistically significant at the significance level of 10%.

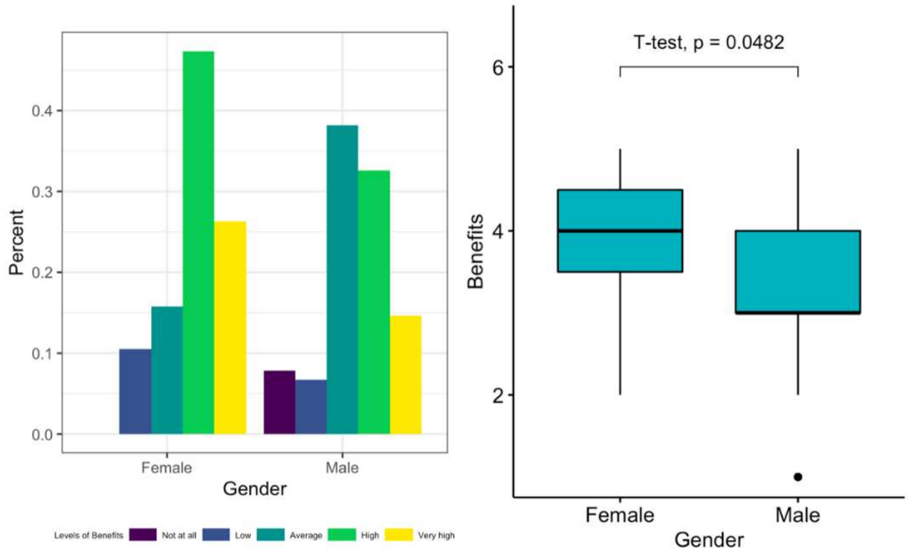

Figure 7. Correlation between gender and seen benefits from the transition to AVs.

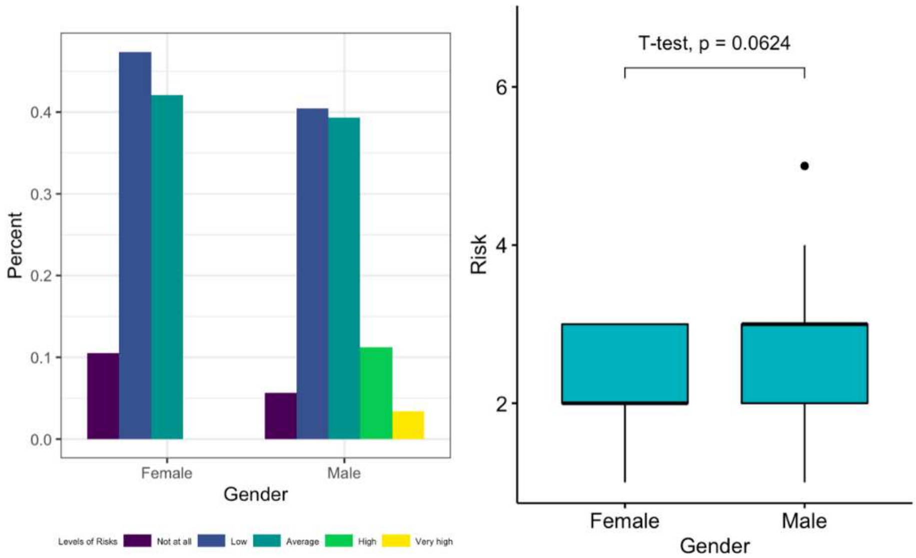

Figure 8. Correlation between the gender and perceived risks from the AV transition.

3.1. Model Building in R

Ordinal logistic regression was performed for the perceived benefits of the transition into AVs as the dependent variable, with six predictors (gender, age, education level, stakeholders' groups, management role and prior knowledge). To fit the OLR model, transformation for some variables were necessary 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, females are coded as 0 and males is coded as 1. The variable for the age is recorded into (0=35 or below 35, 1=

older than 35). The variable for the level of education is recoded into (0 = graduate degree or lower, 1 = postgraduate degree). Transport mode have been excluded from the model to avoid misanalysis. For the group of stakeholder variable, responses from government group are coded as 0, responses from industry group are coded as 1, and responses from general public are coded as 2. Note that traffic authority group is excluded as no responses recorded. The level of management role variable ranged from 0 to 5, so the variable was 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 first two 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 between the following options: 'Never', 'Only heard', and 'Heard and seen'. However, results show that less than 10% of the observations 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 4).

Table 4. Summary of responses to the question on dependent variable 'benefits'.

original categories	Frequency (%)	collapsed categories	collapsed summaries (%)
No benefits at all	7 (6.48)		
Associated benefits of low	8 (7.40)	**Low benefits**	13 (13.88)
Associated benefits of average level	37 (34.26)	**Average benefits**	37 (34.26)
Associated benefits of high level	38 (35.19)		
Associated benefits of very high level	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 Hess=TRUE to have the model return the observed information matrix from optimization (called the Hessian) which is used to get 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 and we would interpret these pretty much as we would odds ratios from a binary logistic regression. Similarly, the coefficients will be translated into odds ratios that are either less or higher than one, (viz., (0, 1)). That in turn, when odds ratios are less or higher than one, means that the predicted probability is decreasing or increasing as the covariate increases, respectively. To get the OR and confidence intervals, we just exponentiate the estimates and confidence intervals. A piece of code from R is shown in Figure 9 and results of the OLR analyses are summarized in Table 6.

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```
## Run an OLR model
OLRmodel_Benefits= polr (Benefits ~ Gender + Age + Edu + Stakeholder +
Manage_role + Prior_knowledge, data = Auto_Vehicle1, 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

The OLR was conducted to determine the influence of gender, age, education level, stakeholders' groups, management role and prior knowledge on people's opinions from Saudi Arabia about the expected benefits that may accompany the transition into AVs. However, before we interpret the results, we need to check the assumptions to ensure that it is a valid model. Initially, multiple linear regression was used to assess any potential issues with multicollinearity between independent variables. A Variance Inflation Factor (VIF) test was performed to check if multi-collinearity exists. Since none of the VIF values are greater than 10 according to Table 5 (not even close to), we conclude that there is no multi-collinearity in the dataset. The second, we need to test whether the relationship between each pair of outcome groups is the same. Table 6 includes the Brant Test to test the 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, then the proportional odds assumption is not violated, and model is valid for this dataset.

Table 5. 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 6 provides the estimated model and displays the value of coefficients and intercepts, and their corresponding standard errors. Based on the direction of the odds, a positive and negative estimate represents a predictor of a higher and lower expectation, respectively. Values below coefficients and standard errors are the coefficient parameters 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 fitted information into this model shows that the overall model is significant ($p < .001$). Furthermore, we discus results in more details.

Table 6. Results of OLR slope coefficients using the perceived benefits as dependent variable.

Main Effects	Parameter Estimates	95% Confidence Interval Lower Bound	Upper Bound	Brant Test Probability
Gender = 1	-1.4384 (0.6226)**			0.19
[Male]	0.2373	0.06419989	0.7619351	

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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)	< .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 $p < 0.01$.

Results show that three out of six independent variables have statistically significant relationship to the dependent variable. The variable gender appears to be the most influential factor (1.4384) where male tended to score lower on the dependent variable with the odds-ratio 0.2373. In other words, for males in Saudi Arabia, the odds of being more likely (i.e., high or average benefits versus low benefits) to have positive expectations from the transition into AVs are 76.27% [i.e.,$(1 - 0.2373) \times 100\%$] lower than females, given that the other variables in the model are held constant. Results differ from other studies which indicate that males are more likely to have positive attitude towards AVs [27–30]. However, our results substantiate other studies which find Saudi females are more likely to have positive attitudes towards AVs than Saudi males (see for example [35]). We speculate 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 ever seen AVs tended to score higher on the dependent variable with the odds-ratio 3.0081. Results found that a total of 92.60% of participants in this survey had previously heard about or see AVs, but those were more likely to be in their middle ages (26-35) and have a higher degree (see Figures 1–3). This represents a significant improvement over earlier research, which revealed that just 66% of participants in 2014 [32], 87% in 2016 [39] and 91% in 2020 [34] had previously heard about AVs. However, this result ties well with previous studies wherein participants who had previously heard of autonomous or self-driving vehicles were more likely to expect high level of benefits associated with the transition into AVs [21,29,30,32,34,40]. Furthermore, our results go beyond previous reports, showing that participants who had ever seen AVs tended to

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be 3.01 times more likely to have positive expectations from the transition into AVs that of people who only heard or never heard about AVs, holding constant all other variables. Therefore, increasing coverage by the Arab visual media on AVs results in higher public awareness of AVs.

The third most influential factor is the category *public* from stakeholder's group (0.8373) where people who belong to public group tended to score higher on the dependent variable with the odds-ratio 2.31. Results showed that people who belong to industry, the are more likely to have positive expectations from the transition into AVs is 29.35% [i.e.,(1-0.7065)×100%] lower than people who belong to government 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 role in their organisation and this variable displayed a positive slope (0.1524), i.e., for a one unit (level) increase in management role, the odds of moving from Low benefits to Average or High benefits are 1.1646 times greater, given that the other variables in the model are held constant. On the calculation of the p-value, it was not large enough evidence (p>.05) that a level of management role had an impact on people's opinions about the expected benefits that may accompany the transition into AVs.

Other variables, though not statistically significant enough, but still worth noting, are the age and education. Based on the parameter estimates shown in Table 6 those aged above 35 and had higher degrees are 1.7075 and 1.9080 times, respectively, more likely to have positive expectations from the transition into AVs. Interestingly, our studies contradict to the findings of other studies where we did not find younger aged are more likely to have positive attitudes towards AV than the elderly [27,29,30,35,41]. Results demonstrate that this is not necessarily true; however, it requires a more detailed investigation.

5. Conclusions

This paper present results of investigation of community views on transition to AVs in Saudi Arabia. Research was conducted at the time when AVs with higher level of automation were relatively new to the KSA public and the market. 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 female and male in expected benefits from the transition to AVs. However both groups considerer that there will be no high risk from the introduction of AVs on the roads of KSA. More generally, we can see that the levels of high autonomous vehicles are significantly well accepted in Saudi Arabia, which also show that people are significantly willing to pay for high levels of autonomous vehicles, but with small proportion of the fully automated vehicle, e.g., level 5. Timeline for the transition into AVs extends to 10 years, according to survey responses. This is well aligned with the KSA government strategy and planning for this important transition in the transport sector. At the same time, ITS and smart cities are on the same timeline as they are directly correlated and interdependent.

Ordinal logistic regression model was used to determine the influence of different factors on people's opinions about the expected benefits that may accompany automotive technology transition. Present findings confirmed the previous published outcomes in literature, showing that Saudi females seem to favour AVs more than conventional vehicles. Results also showed that participants who had prior knowledge of AVs tended to have three times more positive attitude towards transition, that of people who only heard or never heard about AVs.

In conclusion, through increased safety, efficiency and sustainability in term of lowering pollution autonomous vehicles have the potential to revolutionise transport. AVs are key component in the new mobility solutions, known as mobility as a service. There are issues that need to be considered, in terms of moral and ethical dilemmas with fully automated vehicles, as well as and regulatory framework for AVs. Progress is going towards development of comprehensive and reliable solutions for autonomous vehicles by utilising cutting-edge technologies, including big data analytics, IoT, ITS, and AI, 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 to handle the global transition to autonomous vehicles. AVs of the future will be electrical vehicles hopefully running on green electricity.

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