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Research Article

Determining Factors Affecting Acceptance of Autonomous Vehicles using Statistical and Machine Learning Models

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Abstract: The aim of this study was to find out the risks and perceptions related to the acceptance of Autonomous Vehicles (AVs) with regards to different aspects of society. An online survey was used for collection of stated preference data. The data of 465 respondents was deemed suitable for the analysis of this study. Comparison with traditional vehicles and willingness to use had the highest ratings while being tech-savvy had the lowest ratings. Parametric analysis and prediction model were used to analyze the relationships between the willingness to use and participants' characteristics and opinions. The model was developed using artificial neural network. The results show that gender, age, affinity for technology and comparison with traditional vehicles seem to have a significant impact on the perception of participants. This was shown by the parametric analysis performed at a significance level of 5% and later confirmed by the model. The model showed the highest importance of being tech-savvy with 0.76 index followed by comparison with an index of 0.74. A comparison with a similar study from Saudi Arabia shows that drivers in these countries have a significantly different perception related to AVs.

Keywords: autonomous vehicles; Bahrain; driver characteristics; choice prediction, public acceptance

Highlights:

- Determination of acceptance of Autonomous Vehicles (Avs) using various factors.
- Statistical analysis and artificial neural networks used.
- Results compared with a neighboring country and previous studies.
- Providing recommendations to promote AVs and realize their full potential.

1. Introduction

Studies have shown that human error is the main reason for traffic crashes (Fagnant & Kockleman, 2015). Fortunately, autonomous vehicles (AVs) could significantly reduce these kinds of crashes (National Highway Traffic Safety Administration, 2016) since they can sense the traffic environment, navigate based on algorithms, and control their movement by themselves (Zhang et al., 2019). The automation in these vehicles covers two main aspects, firstly, the decision making during the process and the vehicle movement (Kellerman, 2018). The combination of these aspects is the prime reason for their contribution to reduction in crashes. AVs are expected to have serious implications on the aspects of spatial mobility, especially with regards to design of urban streets and parking facilities (Kellerman, 2023). AVs could also improve air quality and fuel efficiency and increase mobility for handicapped and aging populations (Anderson et al., 2016). Additionally, AVs are expected to enhance travel efficiency, and improve traffic flow (Park et al., 2021). As a consequence of these attractive features, the automotive industry has devoted considerable resources to researching and developing AV technologies over the past few years, resulting in significant developments and tests of AV technologies in real-life traffic scenarios (Zhang et al., 2019). Therefore, it could be said that transportation, society, and the environment will all be highly impacted by autonomous driving. However, for continuous evolution of AVs, there is a need to understand the public's initial perceptions and acceptance of them (Liu et al., 2019a). Furthermore, addressing user acceptance issues is essential to successfully introducing AVs to the market, and consequently realizing its full potential which have been forecasted in the above-mentioned studies (Kaan, 2017).

The most significant hurdle to accepting AVs could be psychological rather than technological (Shariff et al., 2017). Müller (2019) has reported that user's perception and societal forms are also strongly influencing the adoption of AV technology. Due to this, it is not possible to improve road safety through AVs unless they are widely accepted, trusted, and appropriately used by the driver (Noy et al., 2018). While AVs can solve a wide range of problems associated with conventional vehicles, the public may not realize such benefits if they are unwilling to accept them. For example, Zhang et al. (2020) believe that AVs' features will not be enough to convince drivers to give up the controls, regardless of their numerous advantages, such as enhanced safety and fuel efficiency. The public's acceptance of AVs can be increased by understanding factors that affect their acceptance.

This research addresses key gaps in understanding public perception of autonomous vehicles (AVs) in car-dependent Middle Eastern countries. Specifically, it focuses on Bahrain, where no prior studies on AV acceptance exist. The study aims to explore the risks linked to public trust and acceptance of AVs, especially among drivers and passengers. Its findings are also compared with data from Saudi Arabia, the UAE, and other GCC countries, offering broader regional insights. Moreover, there is a lack of empirical evidence from users' perspectives, making this study crucial for assessing the potential acceptance of AVs in the region. With this scope of work, the study contributes to existing literature in the following ways:

- Providing an effective approach, with the employment of statistical and machine learning techniques, to obtain the sensitivity of AV acceptance with regard to different user characteristics and dimensions of the vehicle market
- Determining similarities and differences in this issue in the regional and global context
- Providing recommendations for large-scale deployment of AVs which will aid in the promotion of safe and sustainable means of private transportation

The research aim and methodology are shown in Figure 1.

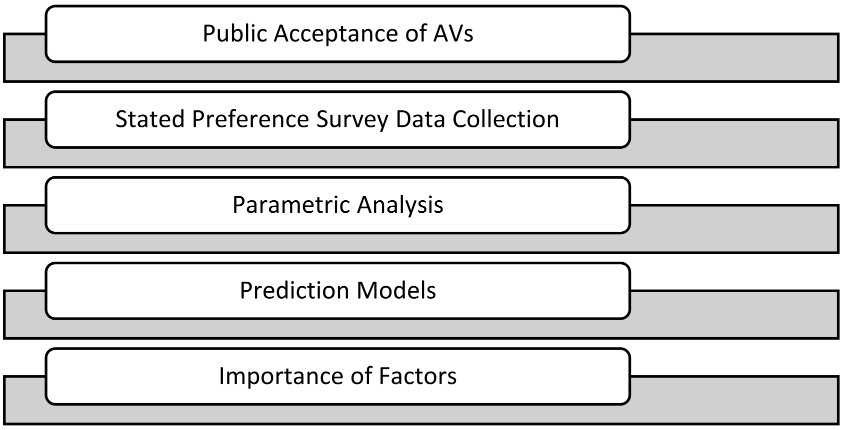

Figure 1. Research plan

2. Literature Review

2.1 User Acceptance

Acceptance is broadly defined as agreeing, approving, or acknowledging something or someone (Maurer et al., 2016). Kaan (2017) distinguishes between two essential forms: consumer acceptance, which involves the willingness to use technology, and citizen acceptance, which relates to the acceptance of its integration into society. Since these types of acceptance are intertwined, they collectively represent user acceptance. However, Kaan (2017) emphasizes that user acceptance is multifaceted and influenced by various factors such as age, education, gender, and previous exposure to technology. According to Faltaous et al. (2024), user acceptance can be defined as “the demonstrable willingness within a user group to employ information technology for the tasks it is designed to support.” Therefore, achieving user acceptance is essential for the successful implementation of any new information system.

2.2 Autonomous Vehicles

In the era of artificial intelligence and the advancement of car technology, AVs are becoming a reality. Semi-autonomous functions are already available in everyday driving scenarios such as parking and cruise control, and fully AVs have started to appear with growing use (Lee et al., 2015). The development of AVs will substantially impact transportation in the coming years (Litman, 2017). For instance, AVs could enhance travel efficiency, improve traffic flow, and decrease traffic congestion (Ribeiro et al., 2022). Additionally, AVs could improve transportation efficiency by reducing energy consumption and the ownership of private cars (Anderson et al., 2016). Moreover, they could significantly reduce traffic crashes caused by human drivers (Ribeiro et al., 2022), which will improve safety on the roads (Liu et al., 2019a). Besides enhancing convenience, reducing travel times and emissions, and requiring less fuel, licensing might not be needed for use of fully automated vehicles, which is beneficial to the elderly and physically disabled (Bornholt & Heidt, 2019).

Currently, there are several policies in place to promote the development of AVs, such as standards for vehicles, regulations, road safety tests, and liability systems (Anderson et al., 2016). Advances in AVs have attracted wide attention and made significant strides. In light of this, AVs will be a crucial component of transportation in the future (Burns, 2013). Furthermore, these advancements will profoundly impact transportation, society, and the environment. For AVs to continue to evolve, a better understanding of the initial public perception and acceptance is needed (Liu et al., 2019b). Researchers have carried out numerous studies on the public’s response to these technologies, especially in developed countries. However, few case studies were conducted in the Arabian Countries which are part of Gulf Cooperation Council (GCC).

2.3 Acceptance of Autonomous Vehicles

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Human behavior tends to resist new technologies, and AVs are no exception (Yuen et al., 2020). Government bodies and automobile companies must understand public acceptance to ensure successful AV adoption (Kaan, 2017). As AVs become central to automotive strategies, understanding what influences consumer acceptance in different markets is vital for tailoring products and marketing approaches (Müller, 2019).

Bornholt & Heidt (2019) highlight that individuals are more likely to embrace AVs when they understand factors influencing their use and purchase. Without such understanding, AV adoption may stagnate. Key influencing factors include safety, convenience, congestion reduction, the ability to perform secondary tasks, licensing requirements, emissions, fuel consumption, cost, reliability, privacy, and security. Alsghan et al. (2021) further emphasizes the role of trust, environmental concern, and comparison with existing modes. Prastiawan et al. (2021) add perceived usefulness and ease of use as influential elements. Gursoy et al. (2019) mention emotional responses and performance expectations, while social norms and past experiences also play roles (Morgan-Thomas & Veloutsou, 2013; Ribeiro et al., 2022). Culture, too, affects attitudes toward AVs (Schoettle & Sivak, 2014).

This study focuses on the most influential factors: safety, willingness to use, and trust. It also considers age, gender, and social context, as these have historically influenced vehicle preferences (Lee et al., 2023).

2.3.1 Tech-Savvy

Being tech-savvy involves a positive disposition toward adopting emerging technologies, including AI and big data (Mallan et al., 2010). Millennials, born around the turn of the century, are notably tech-savvy (Femenia-Serra et al., 2019). As their numbers grow, their influence on technology policies and adoption becomes increasingly important (Siwale et al., 2023).

Studies indicate that tech-savvy individuals are more open to using AVs for personal and business purposes (Dirsehan & Can, 2020). Lavieri et al. (2017) found that young, urban, tech-oriented individuals prefer AV-based ridesharing to private car use. Similarly, Asgari and Jin (2019) observed that tech-savvy individuals favor AVs over public transport.

2.3.2 Willingness to Use AVs

Intentions and willingness drive actual user behavior (6). Several socioeconomic factors influence willingness to use AVs, such as gender, marital status, employment, and education (Hassan et al., 2019). For example, Payre et al. (2014) found that French men were more inclined toward AV use. Hohenberger et al. (2016) noted gender-related differences in AV anxiety and willingness in a German sample, with age playing a moderating role. Alsghan et al. (2021) also reported that younger individuals in Saudi Arabia showed a higher willingness to adopt AVs, influenced by trust and tech-savviness.

2.3.3 Willingness to Pay for AVs

Willingness to pay is a critical driver of technology adoption (Othman, 2021). Without consumers willing to pay for AVs, market integration is unlikely (Cunningham et al., 2019a). Willingness varies globally: in the U.S., U.K., and Australia, over half of survey respondents were unwilling to pay more for AVs (Schoettle & Sivak, 2014). Similarly, Bansal and Kockelman (2017) found that most Americans were unwilling to pay for full automation. Meanwhile, in a broader survey across Australia and New Zealand, comfort and perceived benefits were stronger predictors than awareness or understanding (Cunningham et al., 2019b). Liu et al. (2019c) found that 73.7% of Chinese participants were willing to pay, with differing amounts based on income.

2.3.4 Environmental Viewpoint

Environmental sustainability is increasingly prioritized. AVs may contribute positively by reducing emissions and traffic (Yuen et al., 2020; Jing et al., 2020). They improve fuel economy by optimizing driving patterns and reducing idle time (Bakenbus, 2010). Electric AVs could reduce both air and noise pollution (Rojas-Ruedo et al., 2017), while platooning could enhance road efficiency and fuel savings (Kaan, 2017). AVs and EVs together are key to future sustainable transportation systems (Yi et al., 2018).

2.3.5 Trust in AVs

Trust is defined as "a psychological state comprising of the intention to accept vulnerability based upon positive expectations" (Sharma et al., 2023). It plays a pivotal role in adoption of automation, especially under uncertainty (Yerdon et al., 2017). Trust influences how users interact with and rely on AVs (Kohn et al., 2021). Hoff & Bashir (2015) identify three trust sources: user, environment, and system. Trust in AVs implies a willingness to be vulnerable to technology. This trust is shaped by demographics, culture, media narratives, system performance, and prior experiences (Zhang et al., 2020; Zhu et al., 2020). Higher trust often leads to greater acceptance and willingness to pay (Liu et al., 2019c).

2.4 The Current Study

From the above literature review, it is very clear that the acceptance of AVs depends upon a wide variety of factors which, in turn, depend on the technology awareness as well as users' and travellers' perceptions. It is quite clear that these factors will not be conceived in the same way across the globe. Hence, there is a greater need to investigate AV acceptance factors for specific regions and, if possible, provide a comparison with other similar regions. The present research covers both these factors by being the first attempt to analyse AV acceptance in Bahrain and providing a comparison with its neighbouring which is one of the largest countries in GCC region.

3. Materials & Methods

3.1 The Survey

An online stated preference questionnaire was conducted among residents of Bahrain, an island country located in the Arabian Gulf with an area of 780 km^2 in 2018. Bahrain's population has nearly doubled from 830,000 inhabitants (in 2004) to more than 1.7 million in 2020 (WBG, 2022).

The questionnaire was prepared and distributed using the SurveyMonkey platform via social media channels to ensure broad outreach across various traveler demographics. This method largely achieved diverse sampling, except for limited responses from older individuals and highly educated users. Therefore, the survey offers valuable insights into traveler decision-making. The same questionnaire was previously used by Alsaghan et al. (2021) for a related study in Saudi Arabia, eliminating the need for a pilot. It included three sections: personal details, trip information, and AV-related opinions. Tables 1 and 2 present the parameters and descriptive statistics discussed in the following sections.

Table 1. Description of survey respondents

Parameter	Options given to the Respondent	Frequency of responses for each category	Percent of responses of each category
Age	18-24	162	34.8
	25-34	207	44.5
	35-44	58	12.5
	45-54	25	5.4
	55-64	12	2.6
	65+	1	0.2
Gender	Female	186	40.0
	Male	279	60.0
Level of education	Did not attend school	5	1.1
	Diploma	43	9.2
	Graduated from high school	101	21.7
	Graduated from college	253	54.4
	Master degree	58	12.5
	PhD degree	5	1.1
Language	Arabic	286	61.5
	English	170	36.6
	Other	9	1.9
Hours of driving weekly	Less than 5 hours	108	23.2
	Between 6 and 10 hours	163	35.1
	Between 11 and 15 hours	110	23.7
	Between 16 and 20 hours	44	9.5
	Between 21 and 25 hours	24	5.2
	Between 26 and 30 hours	8	1.7
	More than 30 hours	8	1.7

A key gap in previous studies is that many relied on surveys targeting individuals unfamiliar with AVs, potentially limiting result accuracy (Nordhoff et al., 2017). To address this, the present study provided participants with a clear definition of AVs, detailed objectives, and two explanatory videos—one in Arabic from a well-known documentary, and one by Waymo (2018). The survey was bilingual (Arabic/English) and included screening questions on age and driving license validity. Eligible participants then answered questions on demographics and travel behavior, such as gender, education, language, nationality, income, travel mode, and transport expenses (see Table 1 for participant characteristics).

A non-representative sample of 601 responses was collected during the survey period which was carried out in November 2021. After collecting these responses, they were filtered for incomplete responses and for people who were not resident of Bahrain. It should be noted that non-Bahraini residents are still kept in the sample and analyzed as part of the data. After applying these filters, 465 responses were available for analysis. According to Hair et al. (2010), the minimum sample size should be between 10 to 15 times the number of observed variables. Since the survey included 38 questions, the sample size would be 12.29 times the number of variables used (465 participants/38 variables). As the survey was conducted online, there was no selection criterion applied, except for blocking the respondents who stated not having license or under the age of 18, as mentioned above.

The participants were grouped according to age based on the census age groups. The results showed sample representation in all age groups. However, most of the participants belonged to the younger age group. Most of the participants were male (i.e. 60%). According to the statistics published in 2014, the distribution of gender is almost 50/50 for all age groups in Bahrain (Bushati & Galvani, 2017). This distribution confirms with the national statistics of Bahraini drivers issued by General Directorate of Traffic in 2022 (General Directorate of Traffic, 2022). The mean value for the number of years for which the participants had been licensed was 8.10, and the median was 6 years. The survey was mostly filled by Bahraini nationals (65%), a study by Al-Snan et al. (2020) reported that the population of Bahraini is 46% of the country population, while the rest are expatriates. It could be said that the sample is slightly biased towards the younger male Bahraini respondents. Hence, the results and discussion in the forthcoming sections should be viewed in this context. Most studies in section 2 used online surveys and non-representative samples to cover AV acceptance, similar to the present study. The analysis is discussed based on the opinion of the respondents who dominated the survey.

There were 22 questions in the survey which asked about factors related to AV acceptance, including: comparison, trust, willingness to use, environmental concern, and tech-savvy. These questions were adapted from other studies (Table 2) and can be seen in Alsaghan et al. (2021). These questions were rated on a scale of 1 (strongly disagree) to 5 (strongly agree) except for the first question, which ranged from 1 (extremely uncomfortable) to 5 (extremely comfortable). Figure 2 summarizes the participants' answers to these survey questions related to acceptance of AVs.

Table 2. Survey questions related to AV acceptance

Topic	Question number	Question
Comparison	1	How would you feel about driving on roads alongside autonomous (driverless) cars?
	2	Autonomous vehicle driving will be easier than manual driving
	3	I believe that within 30 years from now, automated driving system will be so advanced that is irresponsible to drive manually
Environmental Concern	4	I am willing to spend a bit more to buy a product that is more environmentally friendly
	5	I rarely worry about the effects of pollution on myself and my family
	6	I'm very concerned about current environmental pollution in Bahrain and its impact on health
	7	I don't change my behavior based solely on concern for the environment
Tech-Savvy	8	I often purchase new technology products, even though they are expensive
	9	Science and technology are making our lives healthier, easier and more comfortable
	10	I know more than others on latest new products
	11	I want to be the first one to buy a driverless vehicle between the people I know
	12	I have little to no interest in new technology
Trust	13	I trust autonomous vehicles and i would like my family to use them
	14	Using autonomous vehicles will decrease my crash risk
	15	I will switch to manual driving from automated driving in case of poor weather
	16	As a point of principle, humans should be in control of their vehicles at all times
Willing to Use	17	Autonomous vehicles will let me do other tasks, such as eating, watch a movie, be on a cell phone on my trip
	18	I think Driving in congested areas is stressful
	19	I find autonomous vehicles to be useful when I'm not feeling well
	20	Using autonomous vehicles will be useful in meeting my driving needs
	21	Using an autonomous vehicle would enable me to reach my destination safely
	22	I find autonomous vehicles to be useful when I'm impaired

3.2 Analyses

This study employs ANN, in addition to factorial analysis, for analyzing the results of stated preference survey. This is expected to provide a higher order understanding of the responses. It is due to the fact that ANN provides more insights into the interrelationships of the variables and the degree of their relationship. All factors were converted into a measure of participants' preference for AVs and then combined. For the ANN model, the mean values for selected category of age, hours spent driving each week, monthly income, and travel time were assigned to the response. Except for the first and last option, where authors chose the extreme value. For instance, for participants who reported driving less than 5 hours weekly, 5 hours was assigned to their response. While in the case of 6 to 10 hours per week driving, 8 hours was assigned to their response. In addition, education was reclassified as an ordered variable, with minimum education valued at 1 (did not attend school) and maximum education valued at 6 (Ph.D. degree).

The output of the prediction model was the likelihood of the respondent shifting to AVs for their work/education trips based on participants' characteristics and their ratings on other factors. The ANN model requires post-processing for interpretation of results and does not provide a clear picture of the relationships which could be shown by a regression model. But the regression model was not applicable in the present case due to the ordinal variable. To provide a comprehensive understanding of accuracy, the correlations between actual and predicted values were calculated in each type of model using the Mean Absolute Percent Error (MAPE) and Mean Square Error (MSE).

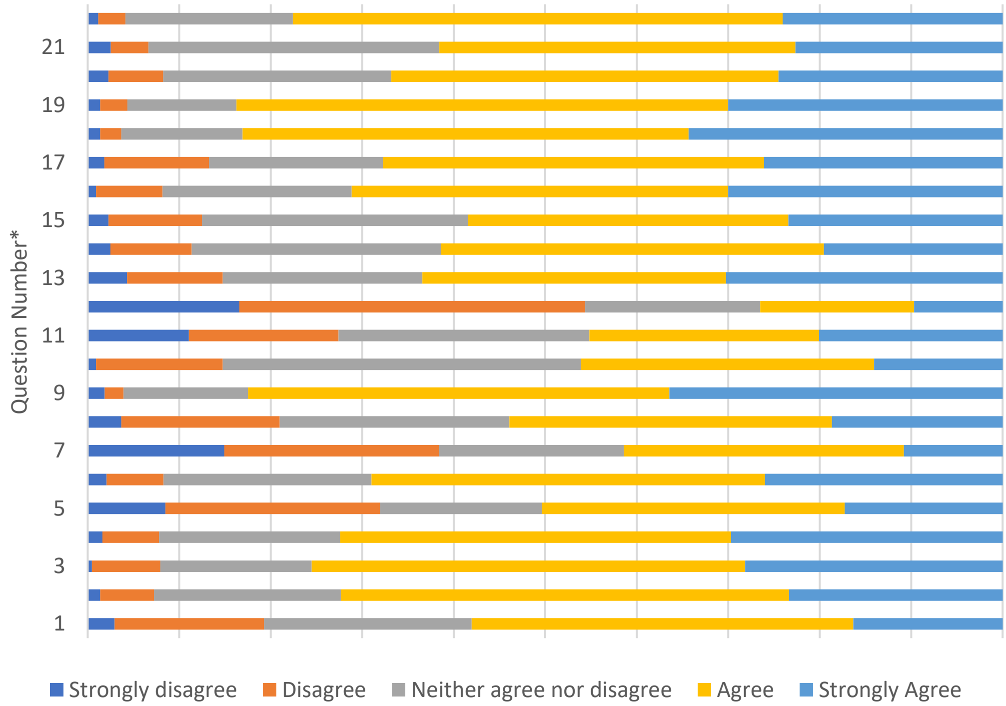

Figure 2. Distribution of responses on questions related to acceptance of Avs
**Refer to Table 2 for details of the text of the questions*

Over the past few years, and with the advancement of artificial intelligence, ANNs have become a popular and helpful model for prediction, pattern recognition, classification, and clustering across many disciplines. ANN is one of many machine-learning (ML) models, and its usefulness has recently become competitive with conventional regression and statistical models (Abiodun et al., 2018). It ANN comprises of three layers: input, hidden, and output. These layers are made up of processing units called artificial neurons, which mimic the behavior of brain neurons (Wang et al., 2021). Input and output layers have the same number of neurons as input and output variables, respectively (Shanmuganathan, 2016). However, the number of neurons in the hidden layer is related to the complexity of the problem (Abhishek et al., 2012). ANNs can be used to deal with unobserved heterogeneity (Mokhtarimousavi et al., 2020).

This study compared the model's accuracy with varying number of hidden neurons to determine the optimum number of hidden neurons. Then the neurons with the highest accuracy were chosen. Simulating the output of a neuron in the hidden and output layers involves applying a function to the weighted sum of inputs and bias. The ANN structure is illustrated in Figure 3. The hidden layer of five neurons provided the greatest accuracy based on this dataset. Activation was performed using a hyperbolic activation function, and the output layer was constructed using a logistic activation function. The ANN model is more effective than regression and parametric models. These models are capable of modelling complex datasets with non-linear relationships (Yamany et al., 2020).

For the development of the model, the training data was further sub-divided into two sets using 2:1 approach for training and cross-validation, respectively. The squared error term was used to compare the performance of models with different hyperparameters. A dual learning mechanism was applied to the ANN model for optimizing the hyperparameters including hidden layers and neurons.

In order to establish the significance of variables over the ANN model's output, two methods were used. Namely, error-ratio and relative importance index. In the former method, a method of superposition is used, and ratios are calculated between the model error with and without a variable, and higher ratios indicate the greater significance of that variable. While in this study, the significance of each factor in the ANN was assessed using the relative importance index, which was calculated using equation 1. The RI value assesses the impact of the variable in terms of its contribution to the weight of hidden neurons in comparison to the total weight associated with the hidden neuron across the network. It is based upon the fact that the ANN model processing is largely dependent upon hidden neurons while input and output layers are used for mapping of input and output variables, respectively. Therefore, a variable with a greater impact on the overall weight of the hidden neuron would have greater impact on the prediction of the model.

$$RI_i = \sum_{h=1}^{H} \frac{|W_{ih}W_{ho}|}{\sum_{i=1}^{I}|W_{ih}W_{ho}|} \tag{1}$$

Where,
RI_i is the relative importance for factor "i"
W_{ih} is the weight between variable "i" and hidden neuron "h"
W_{ho} is the weight between hidden neuron "h" and output neuron "o"

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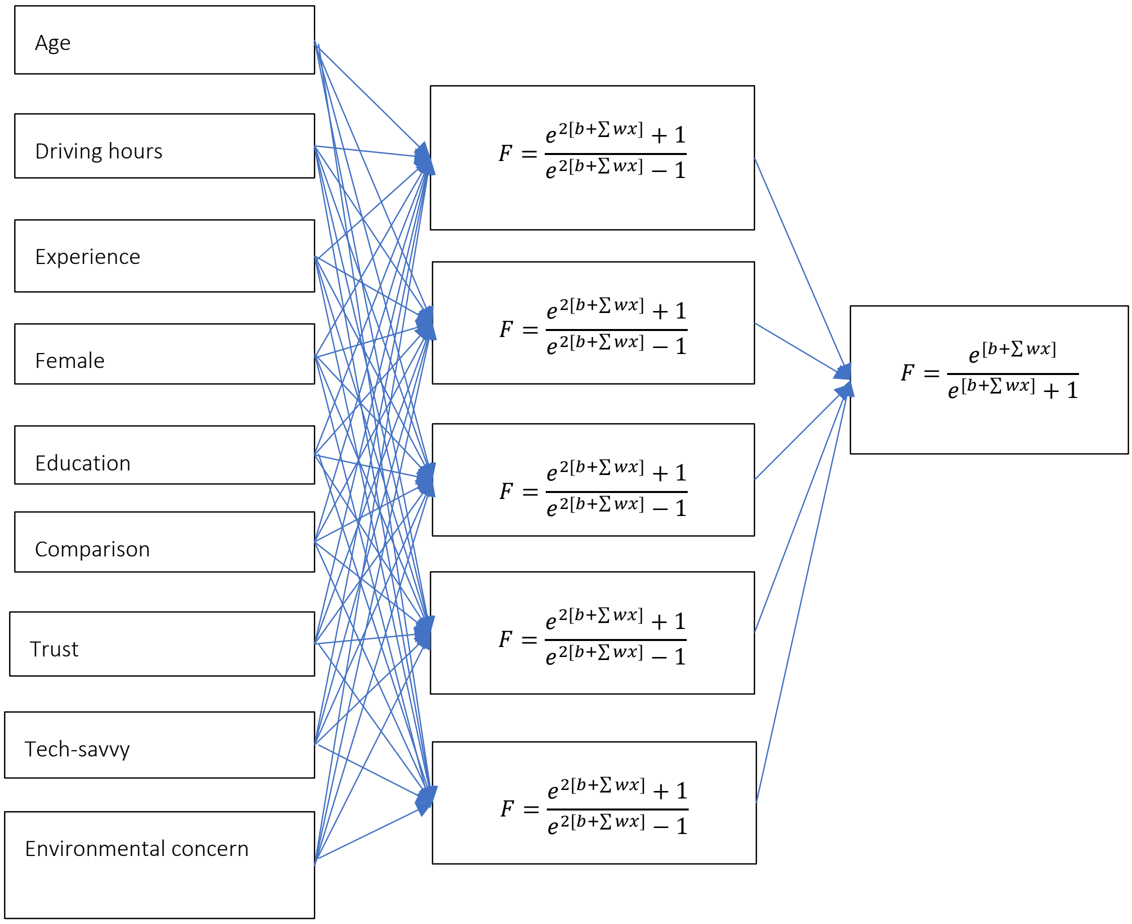

Figure 3. ANN structure employed in this study

4. Results

4.1 Comparison with Traditional Vehicles

Questions 1-3, from the third part of the questionnaire deal with factors of AV acceptance, focused on opinions of respondents with regards to comparing AVs with traditional vehicles. It can be observed from Table 3 that most of the respondents believed that it would be easier to drive AVs than traditional vehicles. They also agreed that AVs would dominate the future traffic stream that driving traditional vehicles would be dangerous. This is also confirmed by the low rating given to statement in question 1, wherein respondents showed disagreement to driving alongside AVs in their traditional vehicles. This could point to the perception that many drivers would not opt to shift to AVs if they do not feel that AVs would be dominant in the traffic stream.

4.2 Consideration for Environmental Concerns

Questions 4-7, for factors related to AV acceptance, were dealing with measuring environmental concerns of drivers as AVs are considered more environmentally friendly. These questions were related to having environmental concerns and to act according to it even at extra cost (question 4 and 6). From Table 3, it is encouraging to observe that these questions received high ranking showing their agreement with the concept. Correspondingly, questions 5 and 7, which were related to lack of environmental concerns or taking it into consideration during decision making, had lower ratings by the respondents.

4.3 Being Tech-savvy

Questions 8-12, for factors related to AV acceptance, were included to gauge the respondent's passion for adopting an AV as a form of new technology. Almost all respondents agreed that new technology has brought positive changes to their lives with higher comfort and convenience, as shown by their responses to question 9 in Table 3. They also showed their interest in adopting and knowing about new technology, in general, which is shown by lower ranking for question 12. However, they did not show the same interest in terms of ratings given in Table 3 for other questions in this section (to adopt new technology at extra cost, or to know about it or to be the first one to take it). Hence, it could be concluded that people would be hesitant about adopting AVs, even if they can perceive their potential positive impacts in terms of reducing driving effort, if their costs are not compatible with the traditional vehicles or they have lack of awareness about their driving mechanisms.

4.4 Trust in Use of AV

Questions 13-16, for the factors related to acceptance of AVs, were focused on investigating the trust of respondents in AVs. In general, the ratings for these questions were very close to each other and on the higher side, as shown in Table 3. Most respondents were in favor of using AVs even for their families and that it would reduce crash risks which were asked in question 13 and 14. However, they also showed strong agreement that drivers should still be cautious while driving an AV, especially in bad weather conditions.

4.5 Willing to Use AV

The remaining questions (17-22), among the factors related to AV acceptance, asked about the opinion related to willingness to use AVs on the basis of different aspects. All questions in this section had a higher ranking which was close to 4. The strongest agreement was for using AVs in congested areas and times, followed by driving when not feeling well. It could be said that respondents do realize the potential benefits of using AVs, especially during circumstances in which they may not be able to perform the driving tasks efficiently.

4.6 Parametric Analysis

ANOVA test was carried out to check the following null hypothesis: "There is no significant difference between the average ratings of different aspects of factors related to AV acceptance".

A significance level of 5% was used for the test. Average rating of each aspect of AV acceptance (comparison, environmental concerns, tech-savvy, trust and willingness to use) was calculated for each respondent before carrying out this test. The results of the test show that the f-statistic of the test had a probability of less than 5% which indicates the above-mentioned null hypothesis should be rejected.

On the basis of the ANOVA test, a box plot (Figure 4) was prepared for the average ratings, so that further insights could be had into their differences. It was found that the rankings for factors for comparison and willingness to use were higher than others, while those for tech-savvy were the lowest. In terms of variation in response, comparison and tech-savvy had the largest variation. While rankings for factors related to trust had least variation compared to others. These observations show that there is a greater division among respondents in the adoption of technology and AVs, while there is a higher consensus related to trust on AVs' performance.

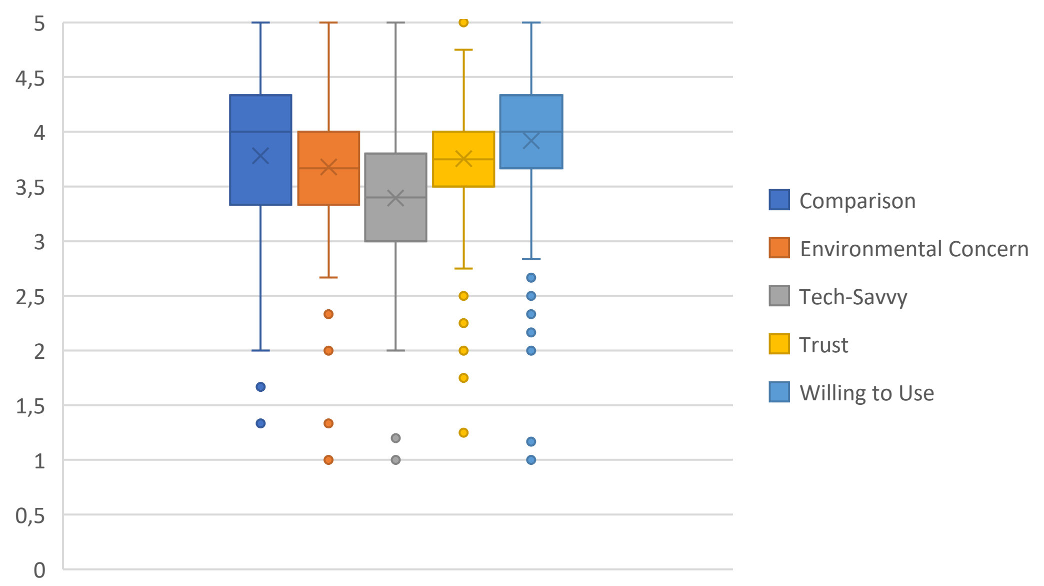

Figure 4. Box plot for comparison of ratings for different aspects of AV acceptance.

Correlation analysis was performed to check if there is any dependence or relation in respondents' rankings related to different aspects of AV acceptance. The results of this analysis are shown in Table 4. It should be noted that correlation is considered significant if the value of correlation coefficient is greater than 0.6 (Sedgwick, 2012). As per this criterion, none of the factors were significantly correlated rankings to the other. However, the rankings for comparison had the highest correlation with trust and willingness to use which was close to the criteria of 0.6.

Respondent characteristics which required categorical responses were tested for their effects using t-tests and ANOVA. T-tests were used to check the effect of gender, nationality and primary language on the rankings, while ANOVA was used to test the effect of educational level on the rankings. The significance level for all these T-tests were set at 5%. The null hypothesis could be generalized as follows:

"There is no significant effect of a specific respondent's characteristic on rankings of factors related to AV acceptance."

It was found that gender had significant effect on the rating of environmental concerns, tech-savvy, trust and willingness to use. When the average ratings for these factors were plotted for different genders (in Figure 5), it was found that female rankings were higher as compared to rankings given by male respondents. Hence, it could be said that female drivers may be more willing to adopt AVs as compared to male drivers.

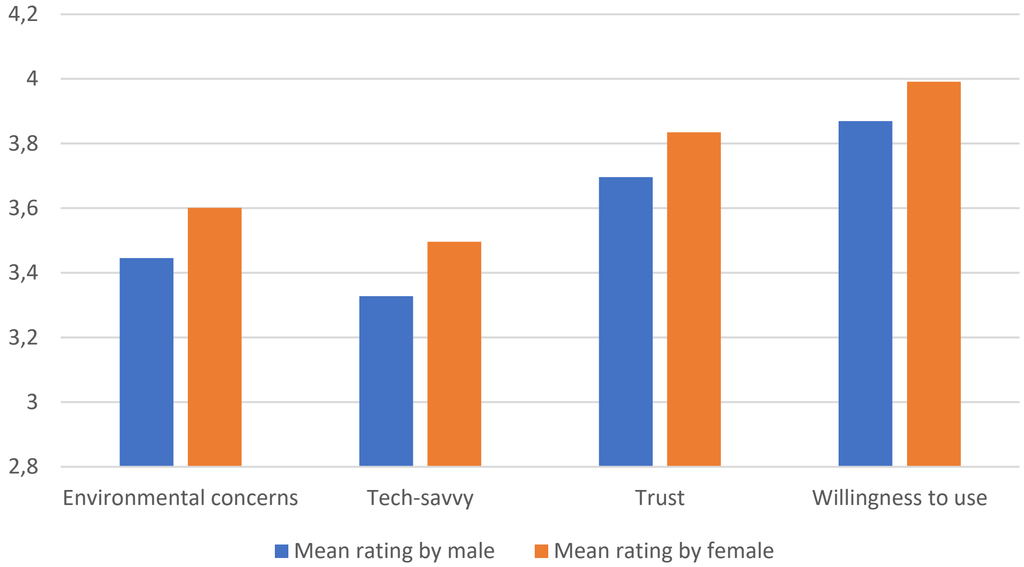

Figure 5. Comparison of factors related to AV acceptance on the basis of gender

T-test for effect of nationality shows that it had significant effect on the ranking of comparison, tech-savvy, trust and willingness to use. Respondents from other nationalities had a higher ranking for these factors which are shown in Figure 6. These respondents could include people from western countries who may have higher greater exposure to AVs, and hence, their opinions are more in their favor.

Figure 6. Comparison of factors related to AV acceptance on the basis of nationality

Primary language had a significant impact on all factors' ranking with people of other languages having rankings, as shown in Figure 7. This could be combined with the effects of nationality and education (presented later). People with higher education may have more awareness about AVs and their advantages and could be more in favor of its adoption.

ANOVA was performed to check the significance of impact of educational level, exclusively and interactively with factors. The results of this ANOVA show that the null hypothesis should be rejected as the critical f-value at 5% probability is lower than the f-statistic of the test. This indicates that educational level had a significant impact on the rankings of the factors. Figure 8 was plotted to have more insights on the effect of education. It can be seen that the there is a definite change in ranking pattern with the college level education. Respondents having college level education have the highest willingness to use while they have lowest ranking for the other factors. They could be young travelers who have a passion for using the new technology but their awareness or consideration for other critical factors is not so high.

People with higher education may be more favorable towards AVs, as shown in Figure 8, due to being more aware of its potential advantages. These trends have been observed in other studies, such as Moody et al., (2020). Differences in other ratings for people graduated from high school, those having diploma and those graduated from college were not so prominent as the two extreme levels. Ratings for tech-savvy were lower for all levels of education.

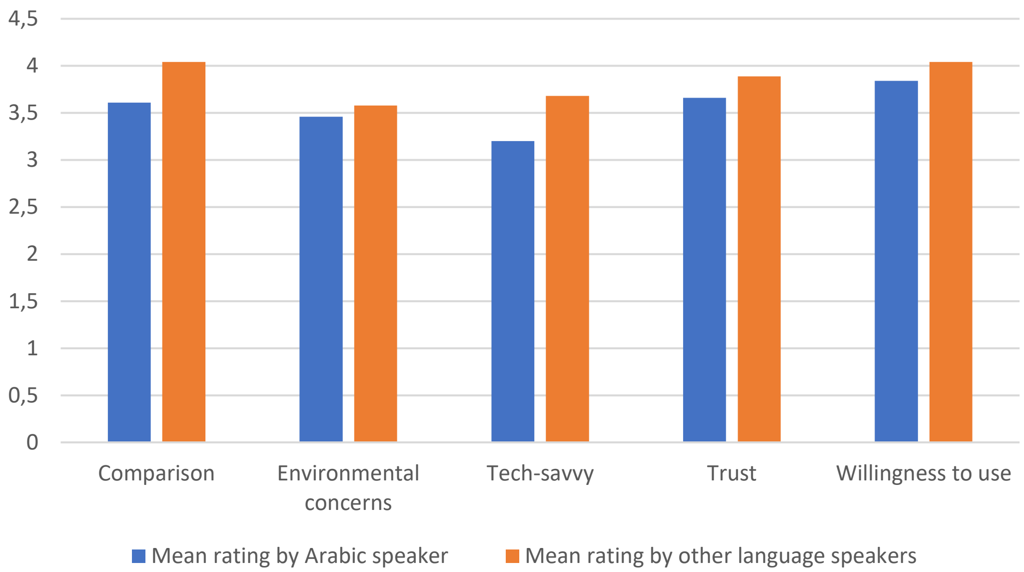

Figure 7. Comparison of factors related to AV acceptance on the basis of primary language.

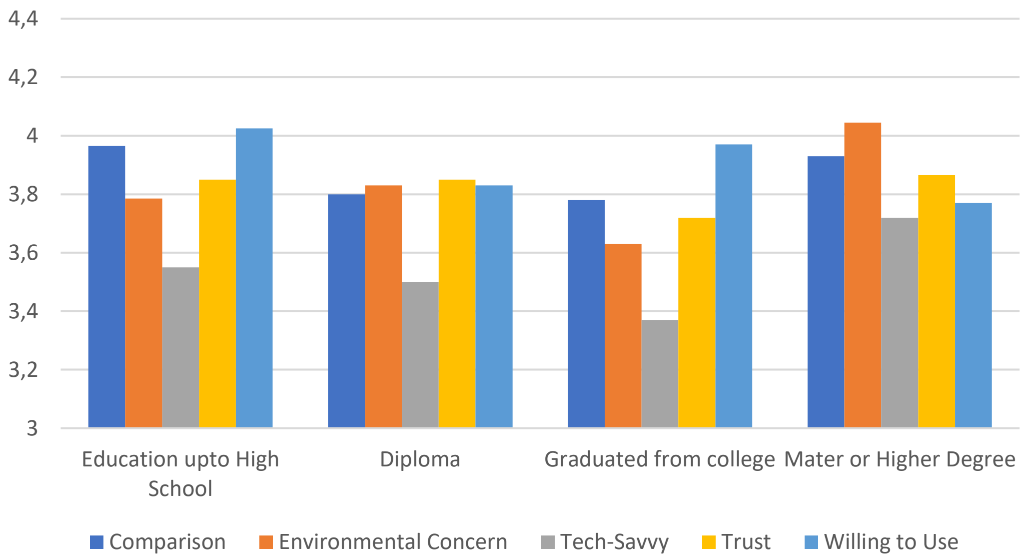

Figure 8. Comparison of ratings of factors related to AV acceptance on the basis of education.

4.7 Comparison with Previous Studies

A similar study, involving same factors related to AV acceptance, was conducted by the authors of this study for Saudi Arabia which is the closest neighbor of Bahrain. The details of which could be found in Alsaghan et al. (2021). Furthermore, certain studies have also found similarities in different aspects among the residents of both countries (Hidayat & Rafiki, 2021). There are studies found in the literature which have tried to cover travelers from both countries due to their common behavior and governmental ties resulting in similar design standards and transport policies which are evident from Canton (2021). Due to these factors, it was deemed important to compare the results of rankings of factors done in Saudi Arabia and the present study. A Mann-Whitney U-test performed to determine the significance of difference between these rankings. The test was performed to check the following null hypothesis at 5% level of significance:

"There is no significant difference between the rankings of factors related to AV acceptance by respondents in Saudi Arabia and Bahrain".

It was observed from the test that p-value for the statistic of the test was less than the prescribed significance level, proving the null hypothesis false, in all cases, except for Tech-Savvy. However, the p-value for Tech-Savvy was also very close to the significance level of 5%. Figure 9 shows a graphical comparison between the rankings of these countries. There is no common pattern with regards to different factors of AV acceptance. Ratings for Bahraini respondents were higher for comparison while they were lower for wiliness to use, compared to their Saudi counterparts. This may indicate that Bahrainis feel that AVs will be more convenient compared to traditional vehicles, but they have other concerns in adopting them while it is not the case for Saudi respondents. The pattern varied for different questions for environmental concerns, tech-savvy and trust.

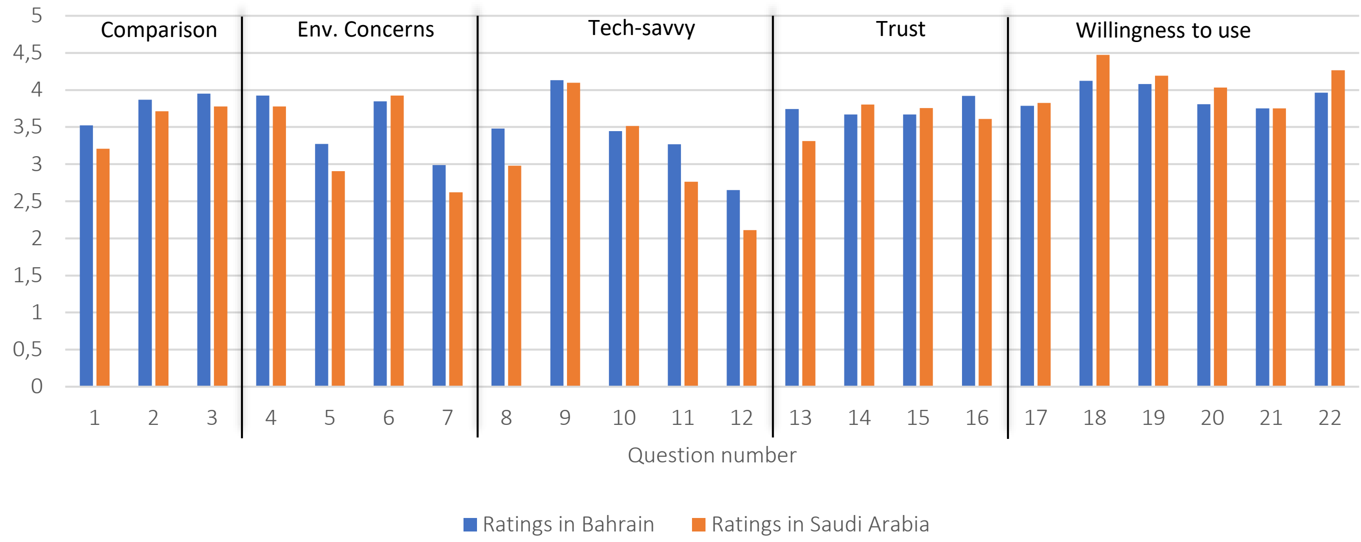

Figure 9. Comparison of mean ratings for factors related to AV acceptance between Saudi Arabia and Bahrain

Another study, covering the entire GCC region, validated the difference in perceptions of travelers from different countries which regards to AVs which is shown in this study as well between Bahrain and Saudi Arabia. However, tech-savvy at individual level as well as the willingness to adopt technological advancements at the government level were found to be important factors for acceptance of AVs (Hafeez et al., 2024). This is further confirmed by another study for the case of UAE, with the additional observation that trust factors are also important for the acceptance of AVs (Hamarsheh, 2024). The latter is also confirmed by a slightly older study for UAE (Al Barghuthi & Said, 2019).

The aspect of trust was highlighted in the Saudi Arabian context by (Shatnawi et al., 2025) who have attributed to the concerns related to cybersecurity and data privacy. The lacking is further compounded by the perceived lack in technical abilities and infrastructure to handle these issues (Farrag et al., 2022).

5. Prediction Model

ANN was developed for predicting the likelihood of shifting to AVs. The accuracy parameters of this model are given in Table 3 and the weights for each neuron in the hidden and output layer are given in Table 4. A 2-phase algorithm was used for estimating the weights with backpropagation and conjugate gradient methods. All variables were normalized for the ANN, using minimax function. Hyperbolic activation function was used in the neurons of hidden layer while logistic function was used for the output layer. These parameters were kept constant throughout the training process while the number of neurons in the hidden layers and their weights were optimized using the above-mentioned methods for minimizing the square error term. These details are mentioned for researchers who may want to utilize this model for prediction purposes using their own datasets.

The weights of ANN shown in table 4 correspond to connection of each of the neuron between the two immediate layers. Thus, there is a weight value for each neuron from layer 1 to each neuron in layer 2. Number of neurons in layer correspond to the number of input variables, while number of weights for each neuron in layer 2 corresponds to the number of neurons in layer 1. The same can be said for the connections between layer 2 and layer 3. Furthermore, the threshold values are intercepts or biases in each neuron to account for unexplained variations. Each neuron in Table 2 is represented by two digits showing the layer and neuron number. Hence, neuron 1 in first layer is shown as 1.1 and that in the second layer is shown as 2.2 and so on.

Table 3. Accuracy parameters for ANN model.

Parameter	Value
Correl-train	0.69
Correl-test	0.64
MAPE-train	20.07
MAPE-test	22.00
MSE-train	0.58
MSE-test	0.67
Training algorithm	BP100,CG22
Normalization	Minimax
Activation functions	Linear, hyperbolic, logistic

Table 4. Weights for ANN model.

	2.1	2.2	2.3	2.4	2.5	3.1
Thresh	1.119677	0.237785	-0.786044	0.362672	-0.282249	-0.200715
1.1	0.239513	-0.060486	0.098987	0.314366	-0.188544	
1.2	-0.048844	-0.259471	-0.176406	-0.007170	0.258535	
1.3	-0.169635	0.126518	-0.047615	0.223194	0.113514	
1.4	0.012192	-0.250884	0.269406	-0.178738	0.279635	
1.5	0.018987	-0.036074	0.146334	-0.137739	0.125102	
1.6	-0.287885	-0.091444	0.008233	0.010746	-0.243004	
1.7	0.529745	-0.301930	-0.297772	-0.046284	-0.072841	
1.8	0.263869	-0.111908	0.023245	-0.037603	-0.048424	
1.9	0.021652	-0.098671	0.135126	-0.027110	0.109871	
1.10	0.097463	-0.040079	-0.037459	0.032628	-0.028267	
1.11	0.400719	0.978884	-0.029185	0.178998	-0.171045	
1.12	-0.052663	-0.035654	-0.150123	0.128635	-0.084235	
1.13	0.199874	0.800193	-0.159557	0.223409	-0.604058	
1.14	-0.037270	0.249500	-0.123664	-0.091578	-0.056993	
1.15	0.020194	0.417603	0.009095	0.159523	-0.002133	
2.1						0.570048
2.2						1.763415
2.3						-0.495856
2.4						0.600756
2.5						-0.562390

As mentioned earlier, the impact of each variable on the ANNs can be estimated by eliminating variables one-by-one and calculating the ratio of error term with and without that variable. Another approach is to calculate the RI value using equation (4). The results obtained from both approaches can be observed in Figure 10. It can be observed that the error ratios for all variables are very close to each other which renders this approach ineffective for comparing the impacts of variables on the likelihood to shift. On the other hand, RI values were more helpful in this regard as they clearly show the distinction of certain variables over the others in terms of their impact on the model.

The highest RI values were attained for the ratings of comparison and tech-savvy, followed by driving hours per week, educational level and age. People with higher education may be more favorable towards AVs due to being more aware about its potential advantages. These trends have been observed in other studies, such as Moody et al. (2020). The impact of age could also be shown with the tech-savvy nature of most young adults, as shown in previous studies (Murniarti et al., 2023). This shows that the decision to shift to AVs depends upon a variety of factors, ranging from perception of drivers to their socio-economic background and trip characteristics. Car ownership, travel time and travel expenses were among factors having the least impact on the likelihood.

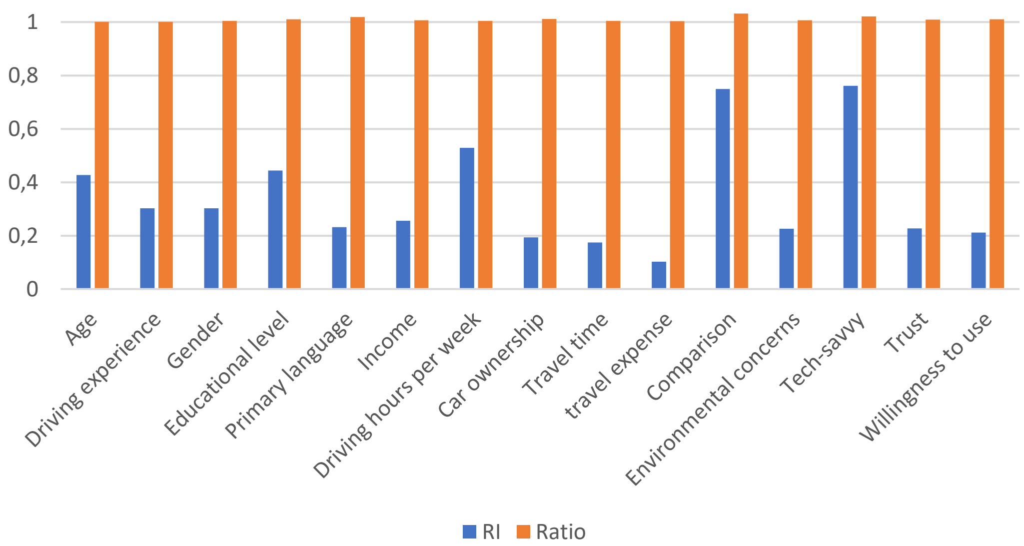

Figure 10. Sensitivity analysis for ANN model.

6. Research Implications

The findings of this research are expected to be important for policymakers and marketers interested in promoting the use of autonomous vehicles (AVs). The study suggests that as AVs become more prevalent in the transportation market, people will become increasingly comfortable using them, leading to a fast and effective realization of the multidimensional benefits associated with their use. Hence, policymakers need to focus on implementing stick-and-carrot approaches to encourage faster and more efficient adoption of AVs on a wider scale in the traffic stream. The findings of this study point to the fact that the acceptance of AVs would require competitive pricing and increasing the awareness of drivers about AVs performance and environmental aspects. This would also increase the trust level of drivers, especially older and mature drivers who are not as willing to adopt the AVs as their younger counterparts. The differences found between respondents from Saudi Arabia and Bahrain underscore the need for further research in different regions and highlight the importance of customized policies and marketing strategies tailored to the specific needs of each region.

7. Conclusions & Recommendations

The aim of this study was to assess the potential risks related to the acceptance of AVs among drivers on the basis of different aspects of the vehicle technology market using a variety of methods including statistical and machine learning techniques. Such combination is rarely used in the studies relevant to this field. Another important point was providing the participants with a brief introduction about AVs before taking their response, which was done in this study. Many studies in the past have not taken care of this aspect while it is expected to have a major influence on their responses. Furthermore, the characteristics affecting the AV acceptance among these drivers were also determined. An online survey was used for data collection and the statistical analysis was applied to this data. The data was analyzed using parametric analysis and prediction model for analyzing shift to AVs. It was found that the sample of the current study had a larger proportion of responses from younger drivers and those having graduation degrees. Hence, the following findings should be considered from the purview of this limitation.

It was found that drivers do agree that AVs will be a better option in comparison to traditional vehicles and they have a high willingness to use them. However, they also showed that their decision will not be based upon their passion for adopting new technology, in general. Rather, they would adopt it by considering the factors related to environment, price compatibility, and their performance in the field. Participants showed significantly higher ratings for factors related to the environment, tech-savvy, trust and willingness to use. Most of these relationships between traveler acceptance and characteristics have been confirmed by previous literature which belongs to other parts of the world. Another distinction of this study is the incorporation of results from other studies from a wider geographical area which is also not common in the present literature. The comparison of the results with others showed that eagerness to adopt technological advancements is a common factor across the GCC region. However, the trust related to privacy and cybersecurity is found to be a concern in the GCC countries, with regard to adoption of AVs.

Model developed to predict the likelihood of shifting to AVs showed that the decision would be highly dependent upon the driver's perception in terms of comparison and tech-savvy. It was also observed that certain drivers' and travel characteristics, including gender, education, age, and hours of driving would also impact this decision. Some of these observations are confirmed by the statistical analysis, as already mentioned above.

It was also clear that drivers who have passion for adopting new technology will be eager to adopt AVs. For future studies, it is recommended that a larger dataset focusing on covering different educational levels and social backgrounds should be collected. Moreover, respondents could also be asked to provide their opinion or reasons which they considered for the rankings. Furthermore, it is also recommended to conduct a stated preference survey with the use of different scenarios in terms of price and environmental impacts resulting from different levels of AVs acceptance (completely, partially). Another possible direction of research is the inclusions of other road users (bicyclists and pedestrians) in the perception analysis. The current research effort was the first of its kind for Bahrain and relied for quantitative analysis. Therefore, recommended avenues of research include incorporation of longitudinal to measure changes in behavior with regards to AVs across time and use of qualitative methods for analysis of data, such as analytical hierarchy process.

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