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Autonomous vehicles between anticipation and apprehension: Investigations through safety and security perceptions

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ABSTRACT

Due to the ongoing enormous infrastructural developments and car ownership culture in Qatar, it could be one of those countries to introduce Autonomous Vehicles (AV) technology at the early stages. Therefore, this study surveyed a number of residents at the State of Qatar to improve our understandings of their perceptions regarding overall safety of AV (General_safety), safety due to the fact that AV could eliminate human errors (Human_errors), safety due to the interactions between Human-Driven Vehicles (HDV) and AV (HDV-AV_interactions), performance in harsh environmental conditions, security, comfort level, travel time, congestion and operational costs. In addition, the study uncovered the relationships of public perceptions towards AV and some other contextual factors with the willingness to adopt it in the future. To study these relations, we relied on a Structural Equation Modeling. Overall, the results showed that respondents had higher and positive perceptions regarding "General_safety" and "Human_errors", however, they were more concerned about "HDV-AV_interactions" and its security. In addition, individuals' preference to shift to AV in the future was positively correlated with their perception level of "General_safety", "Human_errors", Comfort and Travel_time. Regarding ethnicity of the respondents, non-Arabs reported higher concerns regarding AV security, compared to Arabs. Furthermore, interestingly the results revealed that individuals having higher knowledge about AV technology had more concerns on "General_safety" and "HDV-AV_interactions", while they had positive perceptions that AV could eliminate human errors. The findings from this study are anticipated to allow AV manufacturers and other relevant authorities to enhance public confidence towards AV technology by targeting different sub-groups through particular safety or security awareness campaigns.

1. Introduction

Mobility is one of the basic needs of our daily life; however, issues related to safety and efficiency of the traffic system still remain major public health concerns and need continuous further improvements. According to World Health Organization (2018), the number of vehicles increased from 0.8 billion in 2000 to 2.1 billion in 2016. This growth in motorized traffic has several negative impacts on society, economy and environment such as road traffic crashes (RTC), traffic congestion, and air and noise pollution, particularly in urban areas. In this context, every year approximately 1.35 million people are killed while as many as 50 million are injured due to RTC (World Health Organization, 2018). Nevertheless, a human error is involved in more than 90% of all crashes coming from RTC (Dingus et al., 2016; Treat et al., 1979; World Health Organization, 2004). According to Sabey and Taylor (1980), aberrant driving behavior such as perceptual errors (e.g., lack of attention, misjudgment of speed and distance), inexperience, speeding, improper overtaking, tailgating, aggressiveness and impairment are some of the main human related errors contribute to road crashes.

Fig. 1(a) shows the total fatalities in Qatar per year in the period 2015–2020 as obtained from the National Traffic Safety Committee of the State of Qatar. It can be seen from the figure that the total fatalities

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are gradually reduced in Qatar during the last five years Fig. 1(b) represents the fatality rate per 100,000 population for the state of Qatar together with other regions around the world including some neighborhood countries in 2016 (World Health Organization, 2018). As shown, the rate of fatality in Qatar (9.3/100,000 population) was lowest among the neighborhood countries of the middle east in 2016. The rate was comparably similar to Europe and South Korea while it was lower than China, Africa and Americas. It is important to mention that as per the National Traffic Safety Committee of the State of Qatar, the rate of fatality is reduced to 4.4/100,000 population in 2019. This could be mainly attributed to the enormous infrastructural developments and the successful implementation of the National Traffic Safety Strategy that was issued in 2013 to cover a ten years period (2013–2022). This strategy included many interventions that address all aspects of traffic safety towards reducing road crash casualties.

During the past few decades, the automotive industry has been transformed with new technological developments. To this end, autonomous vehicles (AVs) have become one of the most significant and innovative technologies in the automotive and mobility industries. AV technology is expected to change the existing issues in transport system, such as, improving traffic efficiency, reducing RTC and eliminating human errors (Anderson et al., 2016; Fagnant and Kockelman, 2015). Moreover, AVs performance is assumed to be better than human drivers due to their high level of perception (e.g., free of blind spots), and prompt and better decision making (e.g., shorter reaction time and more-precise steering control). However, their functionality is still unclear and has generated much debate concerning how will AV perform in harsh environmental conditions, such as snow, fog, rain, and hail etc. (Sundararajan et al., 2016; Zang et al., 2019). On an individual level, the perception of benefits can be associated with the lower driving stress as no interaction would occur with other cars. Moreover, the time wasted while driving would be used as desired (i.e. eating, working, sleeping, or reading) (Shabanpour et al., 2017; Zmud and Sener, 2017). Another perceived benefit would be the improved access to the mobility especially by physically impaired and elderly people. Furthermore, AVs would dramatically reduce the family-related chauffeuring burdens. In some cases, the usage of AV might increase the access to employment opportunities and education (Anderson et al., 2014; König and Neumayr, 2017). Besides, autonomous vehicles might cause other crash risks such as cyber-attacks (Anderson et al., 2016). The security of AVs is considered as a major concern for the public as individuals hesitate to share their personal data (i.e., location, destination and personal information) with the intelligent transport system (ITS) (Brell et al., 2019; Fraedrich and Lenz, 2016). Also, AVs are exposed to hacking which can cause leaking of personal data or even crashes. Therefore, to assist the globality of AVs, strong and clear safety and security standards must be determined by policymakers. Such regulations can reinforce the trustworthiness of AV technology leading to increased acceptance rate upon its deployment.

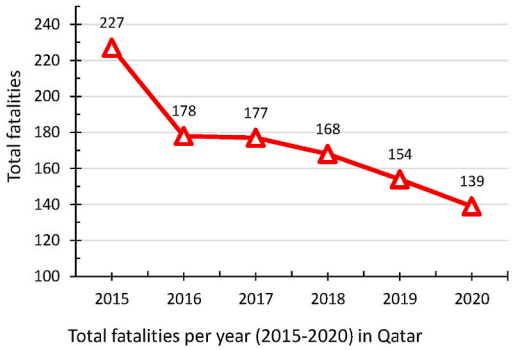
In general, people perceptions about certain things play an important role in their willingness to own or adopt them. Although the idea of an AV sounds very promising, it is still uncertain that this technology will immediately be welcomed into the society by the customers (Liu et al., 2019a; Xu et al., 2018). In this context, some groups may have higher positive perceptions and expectations about AV's safety or security over the other groups (Golbabaei et al., 2020). Therefore, to increase the public acceptance of AVs, it is indispensable to monitor their perceptions of AV risks and benefits closely to emphasize the factors that affect the AVs acceptance (Zhang et al., 2019; Zmud et al., 2016). This is one of the main reasons that public perceptions about AV are receiving significant attention during the past few years, mostly in developed countries.

Based on the recent rapid infrastructural developments and car ownership culture, it is possible that AV technology can be introduced in Qatar at the early stages of AV deployment. Qatar is characterized by a multicultural population of around 2.6 million (Soliman et al., 2018; Timmermans et al., 2019, 2020) with only around 12% of native Qataris while the other 88% are expats from different countries (Planning and Statistics Authority, 2019). In addition, the state of Qatar is ranked 9th in terms of GDP per capita in 2020 as reported by World Economic Outlook Database (IMF, 2020), with more than 1.3 million registered vehicles (World Health Organization, 2018). Therefore, it is crucial to improve our understanding of perceptions of Qatari residents on AV safety, performance in harsh environmental conditions, security, and other benefits/concerns associated to AV considering different demographic characteristics. In addition, it is important to investigate Qatari residents' preferences of shifting to AV based on their perceptions of AV safety, performance in harsh environmental conditions and security, travel time, congestion, comfort, operational costs, and some other contextual factors.

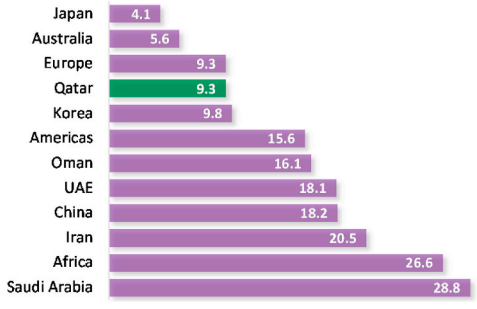
2. Literature review

In general, literature shows that there is a general acceptance and positive perception regarding AV safety (Chikaraishi et al., 2020; Golbabaei et al., 2020; Hulse et al., 2018; Kim et al., 2019; Pribyl and Lom, 2019; Thomas et al., 2020). Literature also indicates that acceptance toward AV would increase as the public knowledge about AV technology increases (Chikaraishi et al., 2020). Moreover, in a study which was conducted in UAE, Barghuthi and Said (2019) indicated that there is a significant correlation between how people perceive safety of AV technology and the idea of adopting it. In addition, a local study targeting Spanish drivers also showed that the intention to use AV was significantly correlated with the individuals' safety perceptions (Montoro et al., 2019).

Based on Golbabaei et al. (2020) review study, perceived risks are the key factors for the acceptance of AV among public. Most of these



a) Total fatalities in the state of Qatar (2015-2020)



b) Fatality rate per 100,000 population for different countries in 2016 (World Health Organization, 2018)

Fig. 1. Crash statistics of the state of Qatar and comparison of fatality rate for different countries.

risks are about safety, cybersecurity equipment/system failure, the interaction between AV and human driven vehicles and not controlling the AV in crash situations. Kim et al. (2019) compared individuals and experts' perceptions of benefits and concerns about AV through a questionnaire. The responses from 98 individuals and 48 experts were compared. Among the different benefits associated to AV, the perceptions regarding AV safety were ranked higher for the factors preventing vehicle crashes, preventing vehicle failure and monitoring drivers' status. Furthermore, individuals' perceptions that AV would reduce travel time and congestion were ranked sixth and seventh, respectively among 14 benefits. In addition, among the different concerns about security, the factor 'damage from hacking' got the highest weights in both groups, while the maintenance cost concern was ranked third among 12 concerns. The study did not investigate the differences between respondents in terms of their demographic factors. Moreover, the intention to shift to AV was not reported. Qu et al. (2019) found a significant positive correlation between the willingness to use AV and the perception that AV would reduce travel time and congestion. Pribyl and Lom (2019) found that the respondents expect that AV would decrease traffic accidents. In addition, the results showed that older respondents were less likely to use AV. Next, Moody et al. (2020) compared safety perception and awareness of AV across 33,958 individuals and 51 countries. Overall, the results showed that highly educated, young, male, fully employed, higher income and respondent who own and drive a vehicle are more optimistic about AV safety compared to the other corresponding groups. In terms of different countries, more economically developed countries reported higher awareness of AV compared to the other countries. The perceived comfort factor has been also reported in the literature. Brell et al. (2019) showed that respondents perceived autonomous driving as more comfortable compared to the conventional driving because they will be more relaxed in traffic.

A study by Charness et al. (2018) investigated the relationship between different demographic factors and individuals' intention to adopt AV technology. The results showed that male drivers had more eagerness to adopt AV and had less concerns compared to female drivers. In addition, the results revealed that younger drivers were less concerned about AV. Another study by Hulse et al. (2018) reported that males and younger respondents showed more acceptance toward AV. The authors argued that this could be due to the fact that these groups are cognizant of their greater objective risks of involvement in RTC. The study also reported that pedestrians perceive AV to be less risky compared to the human driven vehicles.

Another study investigated individuals' propensity toward AV technology for three different clusters of users (i.e., auto-dependent users, all-mode users and non-drivers) using separate structural equation models fitted for distinct sets of attitudes (Rahimi et al., 2020). The findings of the study showed that self-driving features could motivate auto-dependent users to shift to AV technology. In addition, all-mode users were more intended to adopt and pay for AV technology based on driving assistance features. Regarding trip and data privacy, auto users and all-mode users showed higher concerns while no significant impacts were found for non-drivers.

Morita and Managi (2020) conducted a choice experiment by using a random utility model to investigate Japanese consumers' willingness to pay (WTP) for AV technology, and hybrid and electric vehicles. The authors estimated that on average, Japanese consumers' WTP for AV technology Level 5 (i.e., US$2473) was lower, compared to the US market estimates, for instance in Texas Bansal and Kockelman (2017) obtained average WTP of $5857. The authors argued that Japanese consumers' WTP was not adequate to capture enough share in the existing car market. Another study by Bennett et al. (2020) surveyed 211 blind individuals in UK to examine the determinants of their willingness to travel in AVs. The study relied on a structural equation model with four mediating variables including concerns over safety, affordability of AV, hope for the future (independence freedom to travel offered by AV), and skepticism that AVs will meet their needs. The results showed that "hope for the future" was positively correlated to willingness to travel in an AV. In addition, willingness to travel in AVs was influenced negatively by the factors "concerns over safety" and "affordability of AV".

Thomas et al. (2020) reported based on a 3-scale questionnaire, that the highest concerns of the respondents were system malfunctioning, having no driver controls and the performance of the AV in unexpected situations. Moreover, performance of the AV during poor weather conditions and vehicle hacking got high concern scores. The results also revealed that middle age respondents (36–65 years) were highly concerned about AV compared to young and old respondents. Ahmed et al. (2020) studied safety benefits, and safety and security concerns of AV. Overall, around 66% of respondent reported that there will be fewer and less severe crashes on the roads. However, in terms of concerns, around 70% of the respondents reported their concerns about the failure of AV in adverse weather conditions, crashes caused by equipment/system failure and the security of AV against hackers' attack. Results also revealed that respondents who were single or did not possess a vehicle were more likely to expect higher and severe crashes.

In the state of Qatar, a recent study by Alhajyaseen et al. (2020) with 315 respondents, focused on investigating preferences of Qatari drivers regarding privately owned AV and shared AV. The study results showed that drivers in the state of Qatar prefer to use human driven vehicles over privately owned and Shared AVs. However, the study did not consider Qatari residents' perception towards AV safety and security. As indicated in the literature that public perception towards AV safety and security could influence their preferences to adopt this technology in the future. However, individuals' willingness to shift to AV based on their perceptions of AV safety, performance during harsh environmental conditions, security and other (dis)advantages associated to AV, along with other contextual factors has not been investigated in a single model. In addition, studies have reported contradictory results from different regions and driving backgrounds, and therefore, the results from those studies may not be applicable to the state of Qatar with diverse driving population. Therefore, in this study we focused on investigating travelers' perception towards safety, performance and security of AV and their willingness to shift to AV in the State of Qatar. In addition to these comparisons, we aim to include individual socio-economic characteristics and some other contextual factors in the analysis. Finally, studies for the state of Qatar with similar aims have not yet been reported in the literature.

In sum, we believe that the findings of this study, could allow AV's stakeholders to enhance public confidence towards AV technology through particular safety or security awareness campaigns by targeting different sub-groups in the state of Qatar as well as in other Gulf countries with similar demographic characteristics.

3. Research questions

As mentioned above, the objective of this study is to understand how individuals with different demographic characteristics, perceive about different aspects of AV technology as well as the factors that could affect their willingness to shift to AV in the future. The following research questions will be addressed in this paper:

1. Do the levels of perception about AV technology (i.e., AV safety, performance during harsh environmental condition, security, and other (dis)advantages associated to AV) differ between the different socio-demographic characteristics and other contextual factors?
2. Do the levels of perception about AV technology affect individuals' preference of shifting to AV?

4. Methods

The study has relied on the data collected via a questionnaire that was distributed in the state of Qatar. This section describes the development of the questionnaire, sample description, variables definition,

data collection and data analysis methodology used in this study.

4.1. Questionnaire development and sample description

The questionnaire was designed in Arabic and English languages using the Qualtrics platform, which is a web-based survey tool (Molnar, 2019). The questionnaire comprised two different sections. The first section includes questions regarding socio-demographic characteristics of the respondents such as gender, age, ethnicity, average income, educational status, occupational status and some questions related to driving. In the second section, questions related to individuals' knowledge about AV, perceptions of AV's safety, performance in harsh environmental conditions, security, travel time, congestions, comfort, and operational costs, and their preference of shifting to AV. Participants were provided with a brief introduction of the AV technology prior to answering the questionnaire as follow: "An autonomous vehicle (AV) is basically a vehicle which can guide itself with no need of human control. In other word, autonomous vehicle is known as self-driving car, where the computer will take the lead for driving. Moreover, autonomous vehicle uses different kinds of technology. They can be connected with Global Positioning System (GPS) to help with navigation, where the car will display information to users to choose his/her destination. Furthermore, the autonomous vehicle will be provided with sensors and other tools to avoid collisions".

An approval was obtained from Qatar University's ethical committee (QU-IRB) before distributing the questionnaires. The questionnaire was spread through information leaflets posted via different networking organizations and social media platforms. In total 574 respondents filled the questionnaire, of which 435 filled it out in English while 139 filled it out in Arabic. The data was filtered for the respondents of age at least 18 years and their current residential status in the state of Qatar. In this regard, 65 respondents were eliminated from the sample as they were residing outside Qatar and/or were under 18 years old. Thus, 509 respondents were considered as a final sample for the analyses.

Table 1 presents the demographic characteristics of the final sample (N = 509). The final sample was made up by 70.9% males and 29.1% females. The mean age of the respondents was 34.1 years (SD: 11.8 years), ranging from 18 to 66 years. Around 56.8% of the respondents were younger than 36 years of age while 18.9% were older than 45 years. When it comes to the ethnicity, more than 60% of the respondents were Arabs from Asia and Africa, followed by 28.7% non-Arabs (Asians & Africans), 5.3% Europeans and 2.9% north Americans. Regarding educational and occupational status, more than 70% and 67% of the respondents possessed bachelors or higher degrees, and were employed, respectively. Regarding marital status of the respondents, 43% were single, 24.6% were married without children while 32.4% were married with children. Income-wise more than 48% of the respondents had an average monthly income of 10,000 QAR or more. Most of the respondents (79%) owned a car(s) while more than 50% of them were travelling more than 20,000 km of distance yearly. Finally, regarding knowledge about AV, 20.6% of the respondents heard first time about it, 51.5% had a simple background, 20.2% had a good background while 7.7% had a strong background about AV technology.

Table 1
Demographic characteristics of the final sample.

Factor	Levels	Sample	
		Number	Percentage
Gender	Male	361	70.9%
	Female	148	29.1%
Age groups	18–25 years	170	33.4%
	26–35 years	119	23.4%
	36–45 years	124	24.4%
	>45 years	96	18.9%
Ethnicity	Arab (Asians + Africans)	307	60.3%
	Non-Arab (Asians + Africans)	146	28.7%
	European	27	5.3%
	North-American	15	2.9%
	Others	14	2.8%
Degree type	High school or less	104	20.4%
	Diploma degree	46	9.0%
	Bachelor's degree	249	48.9%
	Graduate (Masters or PhD)	110	21.6%
Occupational status	Full time employee	325	63.9%
	Part time employee	19	3.7%
	Student	140	27.5%
	Housewife	10	2.0%
	Unemployed	10	2.0%
	Others	5	1.0%
Marital status	Single	219	43.0%
	Married	125	24.6%
	Married with children	165	32.4%
Average income per month	Not Applicable	134	26.3%
	<5000 QAR	58	11.4%
	5000–10,000 QAR	70	13.8%
	10,000–20,000 QAR	103	20.2%
	20,000–40,000 QAR	96	18.9%
	More than 40,000 QAR	48	9.4%
Car ownership	Yes	402	79.0%
	No	107	21.0%
Average travelled distance per year (N = 402)	<10,000 KM	57	14.2%
	10,000–20,000 KM	141	35.1%
	21,000–30,000 KM	116	28.9%
	31,000–40,000 KM	43	10.7%
	>40,000 KM	45	11.2%
Knowledge about AV	First time I heard about it	105	20.6%
	A simple background from social media, newspaper or internet	262	51.5%
	A good background (know some of its properties	103	20.2%
	A strong background (know what kind of technology are used in AV	39	7.7%

4.2. Variables definition

In total, the study includes eleven main variables of interest, i.e., one related to individuals' preferences of shifting to AV, five related to individual perceptions about AV safety (three variables), its performance in harsh environmental conditions (one variable), and its security (one variable) while five related to individuals' perceptions regarding other benefits/disadvantages associated to AV such as travel time, comfort level, operational costs etc. The variables were re-coded in an ordinal way to represent the level of individual perceptions (e.g., 1 = not safe at all; 5 = totally safe OR 1 = high concerns; 5 = no concerns). Table 2 presents the original statements that were asked in the questionnaires together with the defined acronyms and coding. It is important to mention that the defined acronyms of the variables will be used in the paper hereafter.

4.3. Analysis

The study focused on two different investigations, one aimed at understanding the relationship between demographic factors and individuals' perceptions of AV safety, performance, and security, and a second aimed at investigating individual preferences for shifting to AV based on their perceptions of AV safety, performance, security, travel time, congestion, comfort and operational costs, and some other contextual factors. To identify these causal linkages, a structural equation model (SEM) was developed. The SEMs are useful theory oriented causal networks, which can be used for interpreting a model even with a large number of predictors and responses and their complex causal connections (Grace et al., 2010). In addition, direct, indirect and associative connections can be explicitly modeled in SEMs, which is different than the ordinary regression analyses with implicit model associations (Washington et al., 2020). SEM has a potential to integrate different multivariate techniques under a single framework, such as, factor

Table 2
Variables of interest, their acronyms and coding.

Acronym	Statement/Question	Coding
1.1 Shift_to_AV	Overall, after considering advantages & disadvantages of using AV, would you like to use autonomous vehicle?	1 = Yes, I would use autonomous vehicle 0 = No, I would not use autonomous vehicle
2.1 General_safety	Select one statement representing your perception on the safety of AV.	1 = I think AV are not safe and should not be allowed 2 = I am opposed of using AV, unless I can override the control manually 3 = I need to know a lot about AV and their safety performance 4 = Generally, AV are safe, but I have minor concern that something could go wrong 5 = I have no concern about AV safety
2.2 Human_errors	AV can eliminate the human errors causing vehicle accidents.	1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree
2.3 HDV-AV_interactions	I have concerns about possibility of accident between regular cars and AV.	1 = Strongly agree; 2 = Agree; 3 = Neutral; 4 = Disagree; 5 = Strongly disagree
2.4 Performance	I have concerns about the performance of AV in harsh environmental conditions (such as during raining weather condition)	1 = Strongly agree; 2 = Agree; 3 = Neutral; 4 = Disagree; 5 = Strongly disagree
2.5 Security	I have concerns about securing the autonomous driving system from computer hackers.	1 = Strongly agree; 2 = Agree; 3 = Neutral; 4 = Disagree; 5 = Strongly disagree
3.1 Travel_time	Introducing AV will reduce travel time.	1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree
3.2 Congestion	Introducing AV will reduce the congestion on the roadways.	1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree
3.3 Comfort	AV can make my travel more comfortable.	1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree
3.4 PC	Introducing AV will reduce parking cost	1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree
3.5 MC	I have concerns about increase in maintenance cost	1 = Strongly agree; 2 = Agree; 3 = Neutral; 4 = Disagree; 5 = Strongly disagree

analysis, measurement theory, path analyses, regression analyses, and simultaneous equations. Generally, it is more appropriate to use SEM if more than one regression equations are required for the statistical modeling (Kupek, 2006).

Generally, SEM is comprised of two types of variables, i.e., exogenous variables that act as predictors and endogenous variables that can be considered as response variables. In addition, the endogenous variables are linked with error terms to determine the variances that are not explained by the exogenous variables. Generally, an SEM is defined by a matrix equation (Kuppam and Pendyala, 2001) as shown in Equation (1) with "z" endogenous variables:

$$\begin{vmatrix} Y_1 \\ \cdot \\ Y_z \end{vmatrix} = |YX| \begin{vmatrix} \beta \\ \Gamma \end{vmatrix} + \begin{vmatrix} \varepsilon_1 \\ \cdot \\ \varepsilon_z \end{vmatrix} \quad (1)$$

Where, X and Y are column vectors of exogenous and endogenous variables, respectively, ε is a matrix of parameters linked to endogenous variables, Γ is a matrix of parameters linked to exogenous variables, while ε is a column vector of error terms linked to the endogenous variables. Different from regression models where a set of independent variables predict a response variable, SEM specify systems of relationships with numerous different outcomes and response variables in a more complex causal system (Newsom, 2015). It has also the ability to investigate indirect effects through mediational pathways, with a hypothesis that exogenous variable X causes the response variable Y through the effects of mediating variables m_1-m_x (Newsom, 2015).

SEM is an appropriate analysis approach when testing complicated theories which cannot be predicted by the simple regression models (Alavifar et al., 2012). In the context of this study, the first research question seeks to investigate the relationships between the different demographic/contextual factors with the perception levels of safety, security and other benefits/concerns associated to AV. In addition, the second research question attempts to analyze the causal mechanism of individuals' willingness to shift to AV based on their perception levels. Therefore, we opted for SEM to include a variety of causal relationships in a single model, such as, direct and indirect relationships, correlations between specific parameters and their covariance. It is important to mention that SEM is widely adopted in the literature for evaluating comparably similar theories or research questions, i.e., causal mechanisms of individuals' willingness to shift to AV based on their perceived risks/benefits (Bennett et al., 2020; Liu et al., 2019a; Xu et al., 2018; Zhang et al., 2019), initial trust level (Hegner et al., 2019; Zhang et al., 2019, 2020) and social influence/trust (Herrenkind et al., 2019; Liu et al., 2019a; Zhang et al., 2020) etc.

Fig. 2 illustrates the SEM formulated in this study. The model was achieved after trying different linkage patterns and the final model was modified based on the modification index (Whittaker, 2012). In this regard, the main endogenous variable is "Shift_to_AV", which is directly predicted by "General_safety", "Human_errors", "HDV-AV_interactions", "Performance", "Security", "Travel_time", "Congestion", "Comfort", "PC" and "MC", while indirectly predicted by some other contextual factors. The indirect relations were investigated via the mediating variables (variables in the 2nd column of Fig. 2). The contextual factors include knowledge about AV "Knowledge" (i.e., How much did you know about AV? 1 = First time I heard about it; 2 = A simple background from social media, newspaper or internet; 3 = A good background (know some of its properties); 4 = A strong background (know what kind of technology are used in AV)), respondents' educational level "Education" (low to high), their average monthly income "Income" (low to high), "Car_ownership" (0 = no, 1 = yes), "Age" (continuous variable in years), "Gender" (0 = male, 1 = female), individuals' driving experiences "Experience" (continuous variable in years), "Marital_status" (1 = single, 0 = married/married with children), and "Ethnicity" (1 = Arab, 0 = non-Arab). The factor "Ethnicity" was split into two main groups due to the fact that our sample included few respondents from other regions, i.e., North America (2.9%) and Europe (5.2%). In addition, the causal relationships between the contextual factors and the safety/security related variables are also drawn. The error variances for the endogenous variables are labelled as e1-e11. Finally, the model was enriched with covariances between the exogenous variables (i.e., contextual factors) and error terms associated to endogenous variables separately, that are indicated by double-headed arrows in the figure. In this regard, correlations can be considered as moderate to strong/perfect correlations if the coefficient values are lain between +0.5 and +1 or −0.5 to −1 (Rumsey, 2016). To estimate the model, we used IBM® SPSS® Amos™ Graphics software Version 26. The software not only allows to estimate the direct relations and covariances but also the indirect relationships using bootstrapping technique (Arbuckle, 2011). In addition, the model was adjusted for "Asymptotically distribution-free ADF" approach instead of the "Maximum likelihood ML" available as a default option in Amos™ software. This was done with a reason since ML assumes that the variables are continuous, which could cause overestimation of the Chi-square statists as well as the underestimation of standard errors in case of having ordinal/binary variables in the model. In this regard, ADF method was opted in our model to estimate the parameters (Ding and Lu, 2016; Kuppam and Pendyala, 2001).

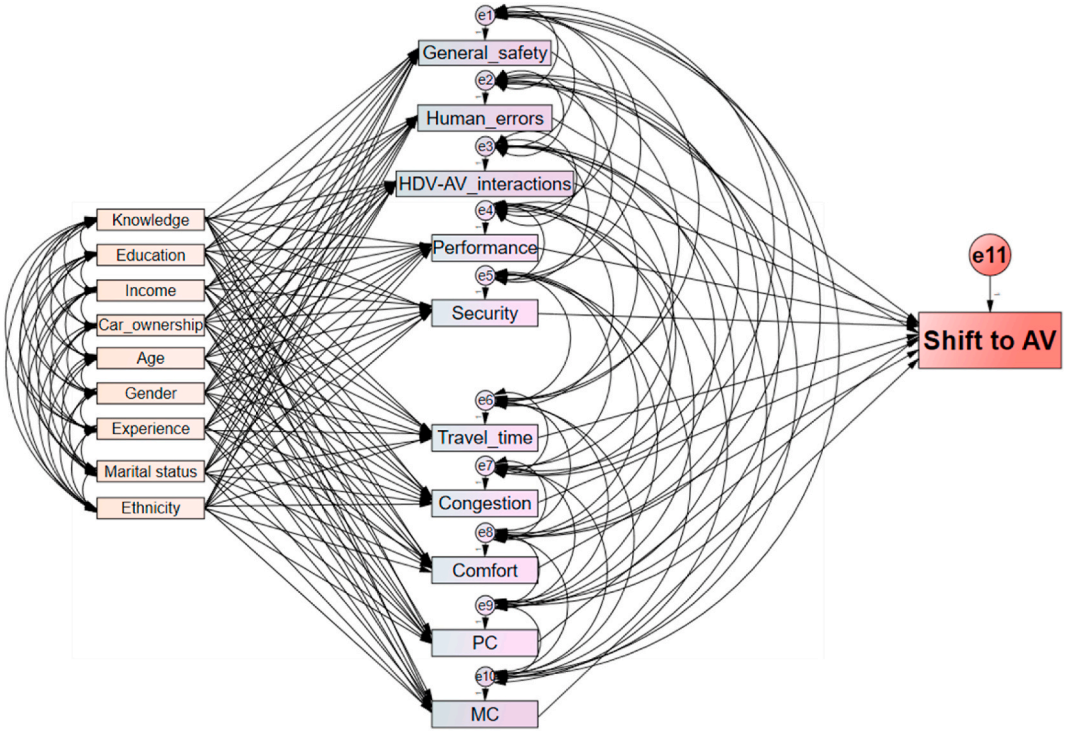


Fig. 2. SEM diagram – connections between exogenous and endogenous variables.

5. Results

The results are split into four different sections. In the first section, overall descriptive statistics of the variables of interest are reported. The second section presents results from the SEM model by reporting the direct causal linkages between the exogenous variables (i.e., demographics and other contextual factors) and individuals' perceptions about AV (endogenous variables: 2.1–2.5 and 3.1–3.5 from Table 2). Next, the third section incorporates the investigations of individuals' preferences of shifting to AV based on their perceptions regarding AV. Finally, the last section presents the goodness-of-fit indices of the model.

5.1. Descriptive scores

Table 3 presents the overall descriptive statistics of the variables of interest. The results indicated that the respondents were less concerned about AV safety in general (General_safety) and the fact that AV could eliminate human errors (Human_errors) as the mean scores were higher than the middle value of 3, i.e., 3.42 (SD: 1.0) and 3.53 (SD: 0.99), respectively. For these two measures (General_safety and Human_errors), more than 50% of the respondents provided with ratings of level 4 or 5 on 1–5 Likert scale. Different from that, the respondents intended to have more concerns regarding AV safety in mixed traffic conditions (HDV-AV_interactions) (Mean: 2.05, SD: 0.88), performance in harsh environmental conditions (Mean: 2.26, SD: 0.95) and security (Mean: 2.24, SD: 0.95). In addition, the mean scores for "Travel_time", "Congestion", "Comfort" and "PC" were higher than the middle value of 3 (i.e., 3.21, 3.19, 3.72 and 3.26, respectively), indicating that individuals had positive perceptions that AV would reduce travel time, congestion on the roads, and parking costs while it will improve the comfort level. However, they had higher concerns regarding increase in maintenance cost "MC" (Mean: 2.21, SD: 0.94). Finally, 65% of the respondents would prefer to shift to AV after considering the overall advantages & disadvantages of using AV (Mean: 0.65, SD: 0.48).

5.2. Individuals' perceptions of AV safety, performance and security

The results of the SEM estimations for individuals' perceptions of AV safety, performance and security etc. are presented in Table 4 for the significant relations only. Relations that were significant at 0.1 level were also included in the table. Interesting results were noticed for the factor "Knowledge" with relation to the three safety related parameters

Table 3
Overall descriptive statistics of the variables of interest.

Parameter	Percentage of responses for each level of scale					Mean Score	SD Score	Sample Size
	1	2	3	4	5			
General_safety	5.5%	10.2%	33.6%	38.5%	12.2%	3.42	1.01	509
Human_errors	3.9%	11.0%	27.3%	43.8%	13.9%	3.53	.99	509
HDV-AV_interactions	26.7%	49.5%	17.5%	4.5%	1.8%	2.05	.88	509
Performance	20.2%	47.0%	21.0%	10.2%	1.6%	2.26	.95	509
Security	21.4%	45.4%	22.8%	8.3%	2.2%	2.24	.95	509
Travel_time	4.3%	19.3%	35.0%	33.8%	7.7%	3.21	.98	509
Congestion	7.7%	16.7%	33.8%	33.0%	8.8%	3.19	1.06	509
Comfort	2.9%	7.7%	19.8%	53.0%	16.5%	3.72	.93	509
PC	5.5%	18.3%	32.4%	32.4%	11.4%	3.26	1.06	509
MC	21.8%	46.8%	20.6%	9.4%	1.4%	2.21	.94	509
Shift_to_AV	(Yes = 1; No = 0)					.65	.48	509

Table 4
Results of the SEM estimations for demographic characteristics (includes only significant relations).

Significant Predictors	Response variable	*Estimate*	*Standard error*	*C.R.*	*Sig.*
Knowledge	*General_safety*	-.132	.060	−2.19	**.028***
	Human_errors	.099	.054	1.83	**.066**
	HDV-AV_interactions	-.105	.055	−1.91	**.056**
	Comfort	.081	.049	1.65	**.099**
Education	*General_safety*	-.099	.049	−2.01	**.044***
	HDV-AV_interactions	-.081	.046	−1.74	**.081**
	Performance	-.099	.050	−1.99	**.046***
	PC	.122	.054	2.26	**.024***
	MC	-.096	.047	−2.02	**.043***
Income	*Travel_time*	-.101	.038	−2.68	**.007****
	Comfort	-.067	.035	−1.92	**.054**
	PC	-.118	.040	−2.92	**.003****
	MC	.076	.033	2.30	**.021***
Car_Ownership	*Performance*	.194	.116	1.67	**.095**
Age	*HDV-AV_interactions*	.013	.007	1.82	**.069**
	MC	.013	.007	1.77	**.077**
Gender	*General_safety*	-.172	.101	−1.70	**.089**
	Comfort	-.278	.108	−2.58	**.010****
Marital_status	*General_safety*	.239	.141	1.70	**.089**
	MC	.265	.115	2.32	**.021***
Ethnicity	*Human_errors*	-.155	.093	−1.67	**.095**
	Security	.189	.091	2.07	**.038***

Significance is indicated with bold font: α = 0.01**, 0.05*, 0.1.

(i.e., General_safety, Human_errors and HDV-AV_interactions). The estimated coefficients of this factor are negative for "General_safety" (β = −0.132, p = .028) and "HDV-AV_interactions" (β = −0.105, p = .056), while positive for "Human_errors" (β = 0.099, p = .066). This indicates that higher the individuals' knowledge about AV, higher would be their concerns on AV safety in general and the possibility of accidents between regular cars and AV. However, higher knowledge about AV leads individuals to have better perceptions that AV would eliminate human errors causing road traffic crashes as well as would improve comfort level (β = 0.081, p = .099). Individuals' perception regarding AV safety in general "General_safety" and in the mixed traffic conditions "HDV-AV_interactions" were also significant for the factor "Education" with negative estimate values (β = −0.099, p = .044) and (β = −0.081, p = .081), respectively. Similar to the factor "Knowledge", individuals with higher educational backgrounds tend to have more concerns about AV safety in general and the possibility of accidents between regular cars and AV. Due to the comparably similar tendencies in "Knowledge" and "Education" for the safety perceptions, it was important to understand if there was any correlation between these two factors. However, the results confirmed a very weak correlation between "Knowledge" and "Education" (r = 0.152) (Rumsey, 2016). In terms of age, the results indicated that as the age of the respondents increased, individuals' concerns regarding the possibility of accidents between regular cars and AV "HDV-AV_interactions" reduced (β = 0.013, p = .069). Moreover, "General_safety" was significant for gender (1 = female, 0 = male) with a negative estimated coefficient (β = −0.172, p = .089) while for the factor "Marital_status" (1 = single, 0 = married/married with children) with a positive estimated coefficient (β = 0.239, p = .089). This indicates that females and/or individuals that were married or married with children had more concerns regarding AV safety in general, compared to males and those who were single, respectively. Regarding ethnicity (1 = Arab, 0 = non-Arab), the results showed a significant negative correlation for the parameter "Human_errors" (β = −0.155, p = .095) meaning that non-Arabs have higher perceptions that AV would eliminate human errors. Finally, the model further confirmed that the safety perceptions were not significantly different between the other demographic/contextual factors, such as "Car_Ownership", "Income" and "Experience".

Different from the results obtained for safety perceptions, the parameter "Performance" was only significant for two factors, i.e., for "Education" with a negative relationship (β = −0.099, p = .046) while for "Car_Onwership" with a positive relationship (β = 0.194, p = .095). This means that individuals possessing a vehicle(s) and/or with lower education levels were less concerned regarding the performance of AV in harsh environmental conditions. When it comes to security of AV, its perceptions significantly varied only between the two ethnic groups (β = 0.189, p = .038). This finding indicates that compared to non-Arabs, Arabs tend to have less concerns about the security of AV.

The model also included some other parameters related to individuals' perceptions about comfort level, travel efficiency and operational costs associated to AV. The parameter "Travel_time" was significant for "Income" (β = −0.101, p = .007), indicating that higher income would lead individuals to have less perceptions that AV would reduce travel time. When asked about the comfort level, the results revealed that in comparison to the other groups, females (β = −0.278, p = .01), individuals with lower knowledge about AV (β = 0.081, p = .099), and/or individuals with higher income (β = −0.067, p = .054) had lower perceptions that AV would make their travel more comfortable. Regarding the cost related parameters, individuals with higher education level had higher perceptions that AV would reduce parking cost (PC) (β = 0.122, p = .024) while higher concerns that AV would increase maintenance cost (MC) (β = −0.096, p = .043). Different from that, individuals with higher income level had lower perceptions that AV would reduce parking cost (β = −0.118, p = .003) while lower concerns that AV would increase maintenance cost (β = 0.076, p = .021). Moreover, respondents age and marital status both showed positive relations with maintenance costs, i.e., (β = 0.013, p = .077) and (β = 0.265, p = .021), respectively. The factor "Congestion" was not significant for any of the demographic or contextual factors.

5.3. Safety and security perceptions vs likelihood of shifting to AV

Table 5 presents the results from SEM model associated to individuals' preferences of shifting to AV based on their perceptions regarding AV. In this regard, the model treated "Shift_to_AV" as the main endogenous variable, which is predicted directly by the other variables of interest from Table 2. In addition, the indirect relationships between demographic/contextual factors and "Shift_to_AV" are also estimated where the other variables of interest (General_safety, Human_errors, HDV-AV_interactions, Performance, Security, Travel_time, Congestion, Comfort, PC and MC) acted as mediating variables. The results of the suggested model for the direct relations showed that "General_safety", "Human_errors", "Travel_time", "Comfort" and "Congestion" significantly affect individuals' preference of shifting to AV. A unit increase in the safety perception level of "General_safety" and "Human_errors" (on a 5 scale) rose the likelihood of individuals' preference of shifting to AV by 7.3% (β = 0.073, p < .001) and 7.1% (β = 0.071, p = .002), respectively. In addition, the estimated coefficients were positive for "Travel_time" (β = 0.049, p = .047), "Congestion" (β = 0.036, p = .095) and "Comfort" (β

Table 5
Results of the SEM estimations for individuals' preference of shifting to AV (includes only significant relations).

Effect type	Significant Predictors	*Estimate*	*Standard error*	*C.R.*	*Sig.*
Direct effects	*General_safety*	.073	.020	3.58	**<.001****
	Human_errors	.071	.023	3.08	**.002****
	Travel_time	.049	.025	1.99	**.047***
	Comfort	.112	.022	5.14	**<.001****
	Congestion	.036	.022	1.67	**.095**
Indirect effects	*Income*	-.023	.039	–	**.023***

Significance is indicated with bold font: α = 0.01**, 0.05*, 0.1.

= 0.112, p < .001) as well. This means that having higher perception levels that AV would reduce travel time, it would reduce congestion level, and/or it would improve comfort level, lead to increase the likelihood of shifting to AV. When it comes to the indirect effects, the model showed significant negative relations for the only factor "Income" (β = −0.023, p = .023) meaning that as the gross income per month increases, it leads individuals to less prefer to shift to AV.

The significant predictors with high estimates (i.e., "General_safety", "Human_errors" and "Comfort") were plotted against "Shift_to_AV" to see the proportion of people who would like to shift to AV technology at each level of perception (Fig. 3(a–c)). As expected, the results showed that as the perception level of each parameter increases the percentage of people who would like to shift to AV increases. At the lowest level of perceptions of "General_safety", "Human_errors" and "Comfort", we found that as much as 92.9%, 70% and 86.7% of the respondents (with perception level = 1) would not prefer to shift to AV as shown in Fig. 3 (a), (b) and (c), respectively. On the other hand, for the highest level of perceptions of "General_safety", "Human_errors" and "Comfort", we found that as much as 71%, 88.7% and 88.1% of the respondents (with perception level = 5) would like to shift to AV as shown in Fig. 3(a), (b) and (c), respectively.

5.4. Goodness-of-fit of the model

Different fit indices are used to evaluate the goodness-of-fit of the model, i.e., Chi-square statistic, Root Mean Square Error of Approximation (RMSEA), Normed Fit Index (NFI), Relative Fit Index (RFI), and Comparative Fit Index (CFI). Among these measures, Chi-square is the most popular test for goodness-of-fit as it provides statistical significance. The threshold values of the other indices of goodness-of-fit contain some discrepancies among scientists. For instance, Schumacker and Lomax (2004) suggest a threshold value of 0.90 for the CFI while Hu and Bentler (1999) recommend a stricter threshold value of 0.95. Table 6 presents the measures of goodness-of-fit of the present model together with the threshold values of fit indices (Bentler and Bonett, 1980; Choudhary et al., 2020). The model accepted the null-hypothesis of Chi-square test which states that the model fits the data, at a high non-significance level (p = .513). Moreover, the other values for these indices were in adequate ranges (i.e., RMSEA < 0.01 ranging from 0.00 to 0.04; NFI = 0.99, RFI = 0.93, and CFI >0.99).

Table 6
Goodness of fit of the present model and threshold values of fit indices.

Fit index	Values of the present model	Threshold values
Chi-square	p-value = .513	non-significant
Root Mean Square Error of Approximation (RMSEA)	<.01 (Range: .00 to .04)	<.08
Normed fit index (NFI)	.997	>.9
Relative Fit Index (RFI)	.935	>.9
Comparative Fit Index (CFI)	>.99	>.9

6. Discussion

This study surveyed respondents with multi-cultural driving backgrounds from the state of Qatar regarding their views on AV technology. The first research question was "do the levels of perception about AV technology (i.e., AV safety, performance during harsh environmental condition, security, and other (dis)advantages associated to AV) differ between the different socio-demographic characteristics and other contextual factors?". In this respect, we found that individuals' knowledge plays an important role in terms of perceptual views on AV safety. Higher knowledge about AV technology leads individuals to have more critical views on AV safety in general, and safety under mixed traffic situations. However, different from that, individuals with higher knowledge about AV technology had positive views on AV safety in terms of eliminating human errors. Albeit, not correlated with "Knowledge", we also found that highly educated people were also more concerned about AV safety in general as well as safety under mixed traffic situations. In addition, they were more concerned about AV performance in harsh environmental conditions as well. These findings

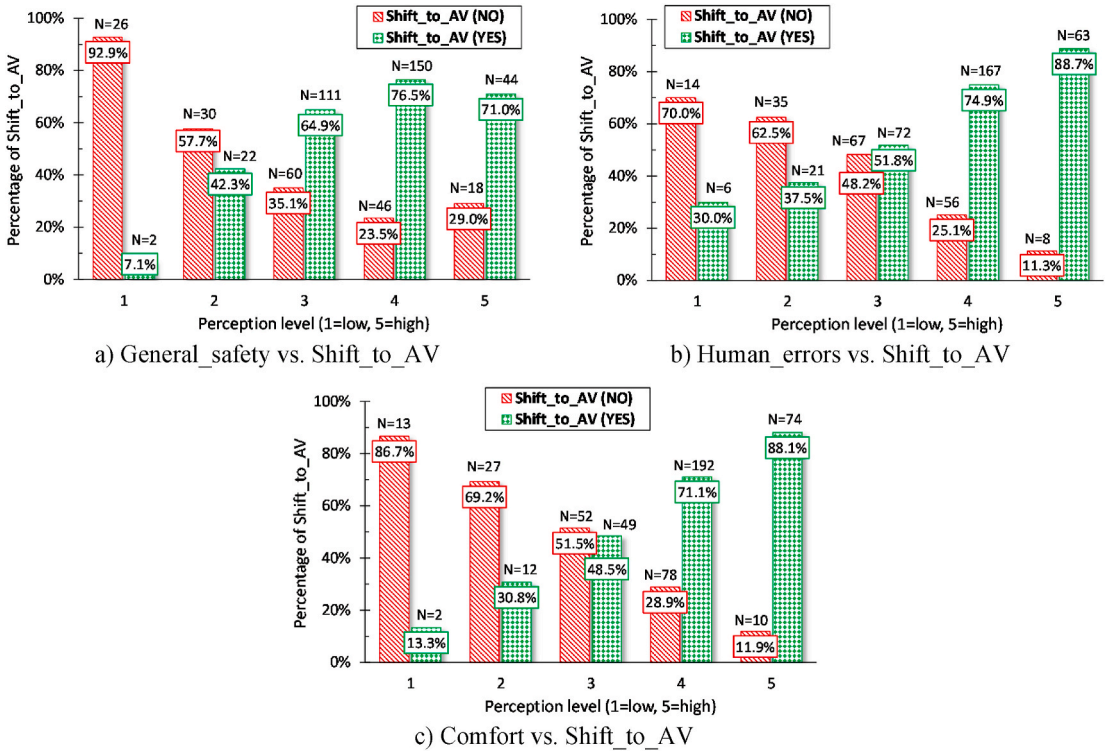


Fig. 3. Percentages of Shift_to_AV for each perception level (1 = low to 5 = high) of the factors "General_safety", "Human errors" and "Comfort".

indicate that even though AVs could eliminate human errors such as drunk and drive, distraction, or fatigue (Kalra and Paddock, 2016), they might not perform accurately in some situations, such as driving in mixed traffic or extreme weather conditions (Pan et al., 2020; Sundararajan et al., 2016; Zang et al., 2019). When it comes to the family setup, married respondents (with or without children) had lower perceptions of AV safety in general compared to singles. One of the possible reasons could be the higher sense of independence in unmarried compared to the married people (Stein, 1975). The finding can also be linked to the finding from another study where respondents were less willing to send their children in a driverless school bus, compared to the traditional school bus (Anania et al., 2018). Although, it has been reported in the literature that younger drivers have less concerns regarding AV safety in general or in harsh environmental conditions (Charness et al., 2018; Hulse et al., 2018; Moody et al., 2020; Thomas et al., 2020), we did not find such significant relations. The only age-related significant effect in our study showed that young people were more concerned about AV safety under mixed traffic situations. When it comes to gender of the respondents, females were more concerned towards AV safety in general. This finding is consistent with a previous study showing that males were less concerned regarding AV safety, compared to females (Moody et al., 2020). In addition, this could be associated to the fact that willingness to take risks is lower in females compared to males (Byrnes et al., 1999).

Compared to Arabs, non-Arabs had higher positive perceptions that AV would eliminate human errors, however, they were more concerned about the security of AV. The overall descriptive statistics showed that around two-third of the respondents were concerned about security of AV. Such finding about evaluating the difference between security perceptions of Arabs and non-Arabs is not yet reported in the literature. However, further filtration of non-Arabs allowed us to find that North-Americans were highly concerned about the security of AV (Mean score: 1.71), compared to Europeans (Mean score: 2.48). In accordance, a survey of public opinion about AV in the US, UK and Australia revealed that the US respondents were more concerned about vehicle/system security from hackers (Schoettle and Sivak, 2014). In addition, this could also be attributed to the safety records of these regions (i.e., Americas and Europe) showing a higher fatality rate per 100,000 population for American regions compared to the fatality rate of Europe (World Health Organization, 2018). Individuals with car ownership had higher perception that AV would perform better in harsh environmental conditions. This could be due to the fact that drivers perceive higher risks and require higher attention levels to encounter the situations during adverse weather conditions (Chen et al., 2019), and therefore, there perception levels could be higher that AV would perform better in those situations.

Besides safety and security related perceptions, the study also evaluated individuals views on other (dis)advantages associated to AV. Females reported lower perceived benefits in terms of comfort level, compared to males. Individual income was significant for most of the variables. Income had significant negative relations with perceived comfort level and the perceptions that AV would reduce travel time. One of the possible reasons for the former finding could be that individuals with a higher income might have possessed more expensive and luxurious vehicles with higher comfort levels compared to those with a lower income (Qu et al., 2019). The latter finding could be explained with a reason that individuals with higher income demand a private owned vehicle instead of sharing it with strangers (Wang et al., 2020). Therefore, their perceptions that the number of vehicles on the roads would reduce due to sharing, are lower than the individuals with lower income. In addition, because of their tendency to afford high-end vehicles, they will be already attaining higher efficiency in their travel time compared to the lower income group. Therefore, their perceptions are lower about AV could further reduce their travel time. Regarding the perceptions that AV would further increase the maintenance costs, individuals with higher income had lower concerns about it. This might be due to the fact that they already have exposure to pay high maintenance costs for their existing high-end vehicles and therefore have less concerns that AV would further increase the maintenance costs.

The second research question was "do the levels of perception about AV technology affect individuals' preference of shifting to AV?". In this regard, Thierer (2013) identified that public attitudes and perceptions play a vital role in assimilation of the new technology into the society. Henceforth, as emphasized by Pettigrew et al. (2019), it is important to understand and continuously monitor public attitudes toward AV from different perspective, which could enhance the likelihood of timely adoption. The overall descriptive analysis revealed that around two-third of the respondents would prefer to use AV in the future. Our results from the SEM model uncovered that the respondents' willingness to shift to AV is significantly dependent on their perception level of AV's safety in general and also to the fact that AV could eliminate human errors. This finding is in line with several studies suggesting that the perceived safety is a key determinant of the public's intention to use AV (Howard and Dai, 2014; Montoro et al., 2019). Regarding the other perceived benefits, "Comfort", "Travel_time" and "Congestion" had significant and positive impacts on individuals' preference of shifting to AV. In accordance, Qu et al. (2019) found that individuals' willingness to use AV is significantly defendant on their perception levels that AV would reduce travel time and congestion while it would allow them to spend their time on other things such as working, texting, phoning, reading, sleeping and eating. Interestingly, individuals' perception level of AV's safety/performance in mixed traffic and harsh weather conditions, security and cost related variables did not affect their preference of shifting to AV. The finding indicates that even though the respondents had higher concern about AV performance during harsh environmental conditions (Mean: 2.26/5), security (Mean: 2.24/5) and maintenance costs (Mean: 2.21/5) in general, this did not significantly influence their choice of shifting to AV in the future. In this regard, Liu et al. (2019a) indicated that for perceived higher benefits (e.g., General_safety, Human_errors, Comfort and Travel_time), people usually bear certain degree of risks. In addition, this could also be attributed to insufficient knowledge about certain risks associated to AV among people (Jing et al., 2020). According to Liu et al. (2019b), public would be less welcoming towards AV technology if they perceive the same risk level as human driving.

Furthermore, from the indirect effects we found that income negatively correlated with the respondents' willingness to shift to AV. This finding is in contradiction with most of the previous studies from different regions showing that income is positively correlated with willingness to shift to AV or WTP (Cunningham et al., 2019; Golbabaei et al., 2020; Moody et al., 2020; Liu et al., 2019c). This could be attributed to the high income level in Qatar in general as well as the large percentage of participants with high income in our sample, i.e., 28.3% of the respondents had an average monthly income of 20,000 QAR (5, 493 USD, as per exchange rate on 2nd February 2021) or more. On the other hand, for instance, only 2.6% of the respondents from Liu et al. (2019c) study had an average monthly income of 20,000 CNY (3, 097 USD) or more. As higher income represents possessing high-end vehicles (Qu et al., 2019), we speculate that compared to the other studies, our sample includes a higher ratio of individuals owning expensive cars. Therefore, the choice of shifting to AV in our model was affected by the mediating variables, where individuals with higher income reported lower perceptions regarding "Comfort", "Travel_time and cost related variables.

The study is important in a way as it targets the multi-cultural population of Qatar, a country with a population of around 2.6 million while over 1.3 million registered vehicles as well as with a higher (9th ranked) GDP per capita (IMF, 2020; World Health Organization, 2018). The findings from the present study could contribute to improve AV stakeholders' knowledge of public perception about AV technology and its impact on their willingness to adopt this technology in Qatar as well as other Gulf countries with similar demographic

characteristics, such as, United Arab Emirates, Saudi Arabia, Kuwait, Bahrain and Oman etc. Our results indicated that certain groups with different characteristics would prefer to shift to AV, such as, those having lower concerns about AV safety while higher perceptions that AV would improve comfort level. However, at the same time higher knowledge about AV technology increases their concerns about AV safety in general. Moreover, individuals with higher income seem to be less welcoming towards AV technology, which is different from most of the other regions. As indicated by Liu et al. (2020) that lower trust level in AV technology not only reduce public desire to ride in an AV but also their willingness to accept the risks associated with a trip in the AV. Therefore, the AV manufacturers and other related authorities may reach out to different sub-groups while targeting particular safety or security awareness campaigns to achieve optimum dissemination. For instance, individuals with higher education level, higher knowledge level about AV technology, females, and who are married or married with children are found to be unconvinced towards potentials safety benefits associated to AV technology. Next, we found that individuals with higher educational level and/or who do not possess cars are more concerned regarding the performance of AV technology during harsh environmental conditions. In addition, females, individuals with higher income level and lower knowledge about AV are found to be skeptical about comfort level of AV technology. Finally, individuals with higher income level were less convinced that AV would improve travel time. In this context, our model predicts that willingness to shift to AV is directly influenced by higher perception levels that AV would improve safety, performance during harsh environmental conditions and comfort level. Based on that, campaigns can be developed to target specific groups of the population by comprising the respective benefits of AV technology (e.g., safety, comfort or travel time etc.) to improve their perception levels and hence the probability of timely acceptance. This is important to be considered in early stages to ensure a timely penetration of AV technology in the Gulf region.

7. Conclusions

This study presents result from a survey to improve our understandings of public opinions towards AV technology in the state of Qatar. In this regard, the study attempted to first investigate individuals' perceptions of AV in terms safety, security, comfort, travel time and operational costs, and then if these factors affect their preference of shifting to AV. To study these relationships, we relied on an SEM while considering the demographic characteristics and other contextual factors as exogenous variables, safety, security, comfort and operational costs etc. as mediating variables, and preference of shifting to AV as the main endogenous variable. Overall, the results showed that the respondents had positive perceptions regarding AV safety in general and that AV could eliminate human errors. However, they reported more concerns, when it comes to AV safety in mixed traffic situations, its performance in harsh environmental conditions and its security. Moreover, the respondents' willingness to use AV was positively correlated with their perception level of AV's safety in general, AV safety due to the fact that it could eliminate human errors, perceived comfort level and the perception that AV would reduce travel time. Females and respondents with higher income seem to be less welcoming towards AV technology. Next, non-Arabs reported higher concerns regarding AV security, compared to Arabs. Interestingly, individuals having higher knowledge about AV technology had critical views on AV safety in general and under mixed traffic conditions, while they had positive views that AV could eliminate human errors. Highly educated people had more concerned about AV safety under mixed traffic situation and its performance under harsh environmental conditions, such as, extreme weather conditions. Finally, family with children had more concerns regarding AV safety in general compared to the other groups.

The public perceptions towards AV must be continuously investigated to assess and evaluate their opinions over time. On this basis, the findings from this study can be used as a reference point for future studies to assess public opinions about AV and their transformation in the future. Based on the recent rapid infrastructural developments and car ownership culture, Qatar could be one of the first countries to help in making AV a reality. In this context, the findings from this study are also anticipated to allow AV manufacturers and other relevant authorities to enhance public confidence towards AV technology by reaching out to specific sub-groups through particular safety or security awareness campaigns in Qatar.

Author statement

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Abdulkarim Almukdad: Writing - review & editing.

Mohammed AlQaradawi: Methodology, Writing – review & editing.

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