QATAR UNIVERSITY

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EXAMINING PREFERENCE FOR AUTONOMOUS VEHICLE (AV) AMONG QATARI RESIDENTS

BY

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ABSTRACT

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Title: Examining preference of Autonomous vehicles among Qatari residents

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Because of growing body of researches that predict the autonomous vehicles to be the future mode of transport. It is important to investigate the preference of Autonomous vehicles among Qatari citizens for fast developing country such as Qatar. Stated Preference survey is distributed to 315 individuals living across Qatar. Based on the participants characteristics, the drivers are exposed to different scenarios and asked to choose one of the presented four modes of transport (Normal car, Private own autonomous vehicles, Shared autonomous vehicles, Public transport).The characteristics of each respondent have an impact on the preferences and attitude toward autonomous vehicles AVs and this was quantified through multinomial logit model. Currently, the key observations were as following:

- There is substantial hesitation toward adoption of AVs in Qatar, with 52% of choice decision that supports normal cars.
- Comfortable scale is an important factor in Qatar because good comfortable scale will increase the utility to use such mode of transport.
- Public transport is considered the least preferred mode of transport in Qatar especially if the individual owns a private car. In other word, people in Qatar give less utility value for SAV and public transport.

Educating the young generation about the benefits of using AVs and public transport will enhance their background regarding the advanced modes of transport and encourage them to use conventional car alternatives in the future.

DEDICATION

It is my genuine gratefulness and warmest regard that I dedicate my thesis to my beloved family who have meant and continue to mean so much to me. I also dedicate this work to my supervisors DR. Wael Alhajyaseen , and DR. Nuri Onat who supported me throughout the process. I will always appreciate his hard working with me, and I will always remember his valuable tips. Last but not least I am dedicating this paper to my grandfather who passed away in 2015 because of liver cancer. May you find peace and happiness in paradise.

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LIST OF ABBREVIATIONS

ACC Adaptive cruise control

AD Autonomous driving

AVs Autonomous vehicles

FAD Fully automated driving

IIHS Insurance institute for highway safety

KARWA Nickname for taxies and buses which provides public transport service in Qatar

MOD Mobility on demand

NHTSA National highway traffic safety administration

PAVs Privately owned autonomous vehicles

PRT Personal rapid transit

SAE Society of automotive engineer

SAVs Share autonomous vehicles

SPT Smart para transit

V2I Vehicle to infrastructure

V2V Vehicle to vehicle

VMT Vehicle mile travel

VOT Value of time

CHAPTER 1: INTRODUCTION:

1.1 overview

Autonomous vehicles (AVs) have been the subject which attract attentions over the last decade featuring in more research studies, journals, articles and even movies. There is no doubt that AVs as a transformational technology will cause a substantial impact on cities. Although there are still many hidden sides related to AVs, from both technical and social aspects -such as behaviours towards fully automated driving which range from excitement to uncertainty- some forecasts have shown that AVs will mitigate congestion, reduce accidents, increase the utility of time spent travelling and improve social life. While other group remain unconvinced, which could be because of limited understanding about the way in which AVs will behave in an existing sophisticated transport system. Within this context, the study was conducted to examine the behaviour of Qatari residents towards introducing self-driving cars. In an attempt to develop smart and sustainable cities, policy makers are inclined towards connectivity, multimodality and use of active modes for travel. In recent times, smart phone-based apps have significantly facilitated the mobility as a service concept in the form of ride sharing and car sharing. However, the advanced modes of transport such as AVs provide more fascinating and exciting travel options, with significant potential to reduce harmful emissions and road accidents. Production race between the two giants Google and Tesla have made it possible to introduce level 4 type autonomous vehicles to be available in the next five years across private sector, at least in the United States (Dai and Howard, 2014). The adoption/preference of AVs is vital to understand in order to investigate the acceptance of this technology. Most of the research around this topic is done in advanced countries, However, it is significantly vital to understand and investigate the preferences of such mode of travel for fast developing economies such as Qatar, where there is a high chance that this mode can be introduced in the market in parallel with advanced developed countries. Therefore, it is important to know how residents of Qatar (given their varied culture and attitudes and beliefs) will respond towards it. AVs provides a unique solution to solve many of complicated problems in transportation. They represent a technological revolution that can affect how individual view mobility. Presence of autonomous vehicle on the streets provides a wide range of benefits, such as enhancing the efficiency, increasing the level of safety, increasing mobility, and decreasing the environmental impacts. According to national highway traffic safety administration (NHTSA, 2013; Fagnant & Kockelman, 2015). Human errors represent around 90 percent from all reasons behind the crashes; AVs can likely reduce number of fatalities and injuries in the roads by avoiding vehicle crashes caused by human errors. Moreover, Autonomous vehicles can offer more efficient use of resources, benefits in terms of time efficiency, and mitigate traffic congestion. AVs enable the drivers to use their time more efficaciously by eating, sleeping, reading, working, or relaxing which gives them an advantage over driving normal cars. Normal cars spend approximately 90% of their average lifespan being unused and parked (KPMG, 2012). AVs have the ability to be repositioned away from crowded areas in order to allow for more important developments such as implementing more green areas in the city instead of having the parking lots. The technology plays an important role in optimizing traffic flow management through the formation of platoons. Thus, it will potentially lead to reduction in traffic congestion, fuel consumption and carbon dioxide emissions. Furthermore, AVs will increase mobility by allowing children, elderly and disabled people who are not able to drive, to commute from one place to another. Nevertheless, this might be considered as one of the disadvantages because of the increased vehicle miles travelled (VMT) and road capacity demands. It is worth mentioning that AVs offers a new travel mode which combine between public and private modes and provides the advantages of both privately owned and shared vehicles. Although, the lack of affordability of privately-owned autonomous vehicle and the absence of comparable transportation mode choices have resulted in the presence of shared autonomous vehicle, introducing level 4 and 5 AVs have the ability to eliminate many obstacles associated with shared autonomous vehicle. This can be done by providing better service demand and enhancing user's ability to access the vehicles.

This study examined who will use autonomous vehicles among Qatari residents under certain circumstances. A well-organized survey designed through a website have been distributed inside and outside Qatar university. The survey was made of 6 parts, with the first part including Characteristics of the individual (socioeconomic questions), second part about driving habits which include questions related to (driving experience, traveling distances, ownership, and cost of the owned car) this part is important to influence the decision and shift to use privately owned/shared autonomous vehicle. Third part provide questions about autonomous vehicle to examine the level of awareness of the participant about the subject. Forth part contain questions related to travel behaviour, mode choice, as well as include questions associated with impacts of AVs on the environment, and final part contain stated preference scenarios to gain insight into the volunteer attitudes toward AVs. Qatari Residents attitudes regarding AVs are important since the public controls the governing policies, future investments in infrastructure, and demand for the technology.

1.2 Scope of the study:

The thesis will cover previous study work on introducing the autonomous vehicles and the factors that push or pull people from using this mode of transport. Later, an online survey, made of 5 parts: socioeconomic questions, driving habits questions, questions about autonomous vehicles, questions related to travel behaviour, and last part includes the SP-scenarios was developed and distributed. This survey will be distributed among the Qatari citizens targeting both of public transport users and people above 18 years old with Qatari driving license. In consequence, collected data lead to model estimation. Finally, conclusions and recommendations for introducing autonomous vehicle in Qatar are presented.

1.3 Significance of the study:

- It reveals the most effective factors that strongly influencing the behaviour of participants toward using self-driving cars.
- it investigates how much Qatari citizens know about Autonomous vehicles and to which extent the people living in Qatar are willing to shift and use it in future.
- It shows which mode of transport the Qatari citizens prefer more among four mode of transport.
- Set a foundation for the future in-depth studies on the self-driving cars and their overall effectiveness.

1.4 Study Flow chart:

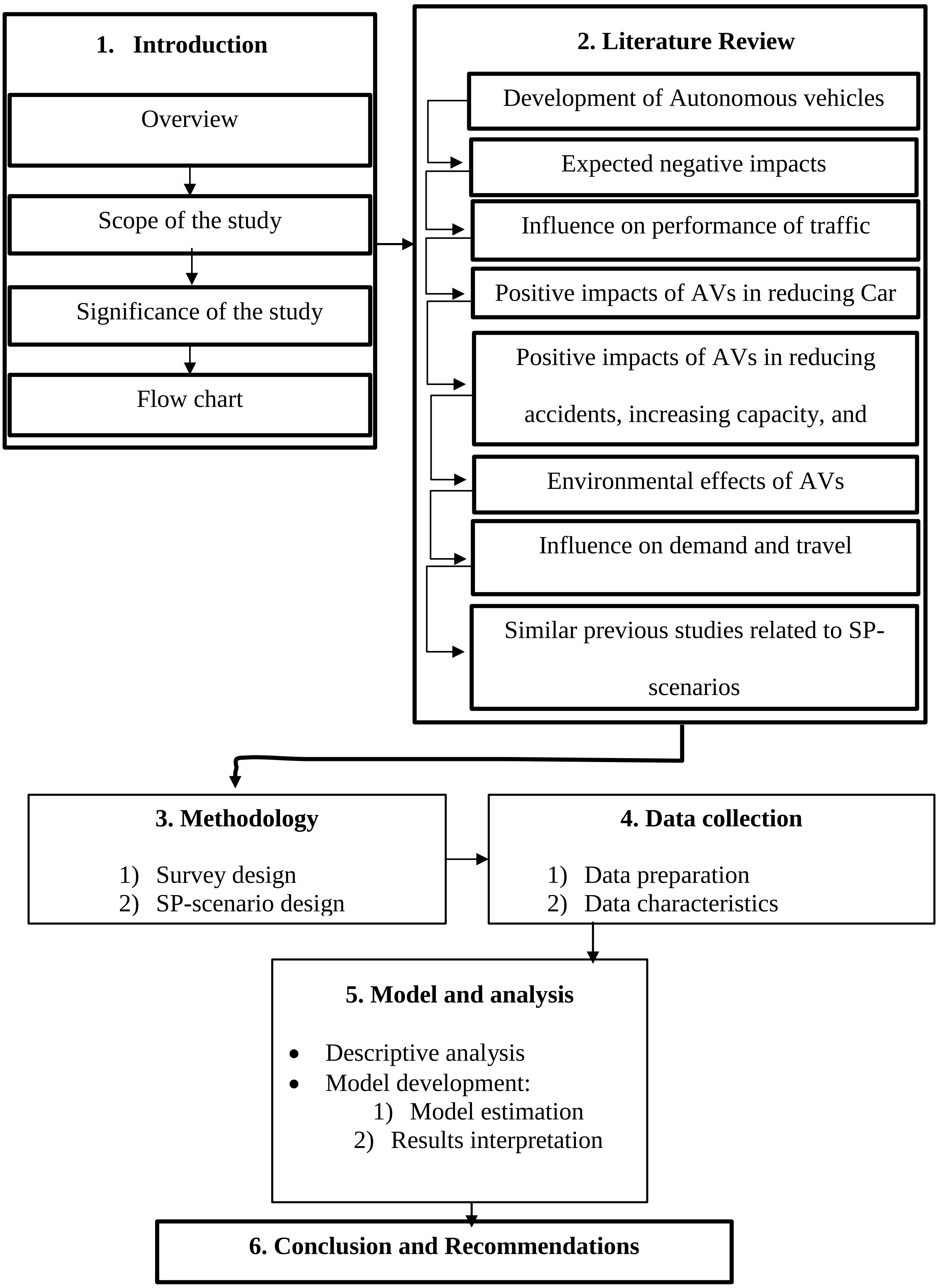

Figure 1. Frame work of the thesis

CHAPTER 2: LITERATURE REVIEW

2.1 Development of AVs:

According to (NHTSA, 2013) US national highway traffic safety administration, a system classified into 6 different levels starts with fully manual system being level 0 and ends with fully automated system which forms level 5. The classification system depends on driver interference and attention required while driving. Most people define autonomous vehicle as the highest-level car among the 6 levels, which means the vehicle can travel from one place to another independently. However, there are some AVs which can perform self-driving under certain conditions.

2.1.1 Automation level definitions provided by society of automotive engineer international (SAE):

SAE is an educational and scientific non-profit organization dedicated to the advancement of mobility technology to serve humanity. According to (NTC, 2016a) SAE defines 6 levels of automated driving from level 0 to level 5 as following:

- Level 0: does not have sustained car control
- Level 1/ hands on: control on the vehicle can be done in two ways, by the driver and the automated system. One example could be the adaptive cruise control, in which the automated system will take control over the speed of the car and the driver will control the steering. Whereas during the parking process, the automated system will take control over the steering, while speed is under a manual control. However, the driver should be alert and ready to control the vehicle at any circumstances.

- Level 2: at this level the automated system will be designed to take full control of the car (steering, speeding, braking). The driver must be conscious and aware to switch to manual control and take the lead if the autonomous system fails to respond. During the second level the contact between hand and wheel is often compulsory, to make sure that the driving person is ready to take control.
- Level 3: at this level the driver can do different tasks and use his attention away from driving. The vehicle will be well-designed to handle urgent situations that need an immediate response. The driver should be aware to control the car within a limited time, when called upon by vehicle to do so. At level 3 the vehicle have something called traffic jam pilot. When switched on by user, the vehicle immediately will control all aspects of driving in scenarios when the speed of the car is less than 60 kph (37mph). This characteristic can be activated only on highways with barriers dividing one stream of traffic from opposite traffic.
- Level 4: it is similar to level 3, except that the driver can sleep, relax and do any other tasks with no driver attention is needed for safety issues. Manual driving will be used under special circumstances such as traffic jams. Outside this condition the vehicle should be able to drop the driver safely on the requested distention.
- Level 5: no need for human interference at this level, such as robotic taxi.

2.2 Influence on performance of traffic system:

One of the advantages predicted while using AVs is enhancing traffic flow (Shladover, 2009). The anticipated improvements are in the form of increased vehicle platooning, increase traffic throughput and increased traffic intersection capacity. There is much hope that automated systems will be able to solve traffic congestion problems on freeways by eliminating imperfect human driving behaviour and stabilising traffic flows (Fagnant & Kockelman, 2015). Currently, there is not enough evidence on how self-driving cars will behave, in addition there will be normal variations between different brands. However, their likely influence on highway traffic can be predicted by referring to a large body of ongoing research related to adaptive cruise control systems (ACC). These systems provide lower level of automation by NHTSA. In which, it controls the longitudinal movement of the vehicle by gathering local information from the vehicles front looking sensors, which control the motion of the preceding car and try to reach the optimum speed when it is safe to do so.

2.3 Accidents reduction:

One of the most important advantages AVs can provide is that it reduces the number of crashes and accidents which will result in a further reduction in congestion and increase travel time reliability. Since the human errors constitute more than 90% of crashes, therefore it is logical to predict that AVs will be safer to use. According to Fagnant & Kockelman (2015), even if there is a probability for hacking and machine breakdowns to occur, still AVs do not get distracted, do not drink or use drugs while driving do not drive tired, and do not break laws as what humans do. These were the primary factors announced by the U.S NHTSA during 2012. As pointed out by (Petit & Shladover, 2015), benefits depend on the proportion of self-driving cars in the mixed traffic and how strong the communication will be between vehicles and infrastructure.

2.4 Capacity and comfort of the intersection:

Due to more conflicting flows, intersections introduce more challenges to AVs than freeways. Recent researches have presented new methods of intersection controls integrating AV technology, which will improve intersection capacity. Tachet et al (2016), mentioned that Some involve fundamental departure from the conventional signal controls for example the slot-based system, for which market acceptance would be a challenge; others are considered to work with a mixed flow of normal passenger cars and AVs. Majority of these systems require V2I/V2V communication. On other hand, passenger comfort might also improve by using the autonomous intersection management system, especially given that likelihood of eliminating the necessity for roundabouts that are prevalent in suburbs. Small roundabouts found in local areas are considered as one of primary causes of bus passenger discomfort because they are difficult for buses and large vehicles to negotiate. If all vehicles are autonomous then there will be no longer need to construct more suburban roads. AVs could be synchronized safely using allocation mechanisms and automated negotiation.

2.5 Predicted environmental effects of Autonomous Vehicles:

In the last decade, significant efforts have been conducted to permit full automation driving. As mentioned before in this paper, society of automotive engineers (SAE) defines the six levels of automation in traffic. These levels include no automation (0) driver assistance (1), partial automation (2), conditional automation (3), high automation (4) and full automation (5). This paper refers to both high automation and full automation (level 4- level 5). By the beginning of 2030 it is predicted that the full self-driving cars which do not have a manual mode will be available. Some studies have predicted that level 4 AVs and level 5 AVs will reach a market share of minimum 11% to maximum 42% during 2035 [Trommer, S.; Kolarova, V.; Fraedrich]. This rapid development in the technology of the vehicle raises a question about the evaluation of such development from a sustainability perspective. Nevertheless, it is vital to understand that this technology is neither eco-friendly nor the opposite. This always depends on the AVs effects on transportation such as, on travel behaviour or on traffic system performance.

2.5.1 Positive environmental impacts:

Self-driving cars could operate more efficiently than normal passenger cars, and thus could decrease the fuel consumption and environmental impact [Ringenson, T.; Höjer, M.; Kramers, A.; Viggedal, A.]. Autonomous driving [AD] would reduce vehicle emissions up to 94%. Linked AVs can mitigate or eliminate sudden stops and moves in traffic jam. In which, platooning is one way to enhancing the safety of the traffic, optimize flow of the traffic, and decrease harmful gaseous emissions such as CO_2 because vehicles can share data and control driving speed, coordinate time plus distance headways between vehicles, and braking characteristics. Consequently, consumption of energy could be reduced. As crashes can be eliminated by using AVs, vehicles need lower safety requirements such as steel constructions and airbags and would accordingly weigh less. Therefore, engine performance will be reduced, which will result in decrease energy consumption, decrease CO_2 emissions, and considerably reduce environmental pollution. However, the increased entrée of travelling by cars (by elderly, younger ages, and disabled people) is expected to be higher in Vehicle Miles

Travelled (VMT) which will result in a decrease in the AV-related advantages. Thus, there is a suggested ability to lead to automobile-oriented advancement, but with a need of fewer number of cars and parking. Which will lead to drops in the number of crashes, congestion benefits, less and full efficiency parking. In addition, considering the increase in VMT. Kockelman and Fagnant (2015) predict yearly profits to the US economy which would reach $196 billion (expecting a 90 percent self-driving market share).

2.5.2 Negative environmental impacts:

The major concerns are the different sorts of rebound effects which can happen due to resource saving [Sorrell, S. Energy]. For example, increasing vehicle efficiency in the mobility section will lead to increase car mileage, additional driving style that is energy-intensive or could obtain a larger or an extra vehicle [Becker, S.]. The rebound models suppose that the savings in cost or time resources which come from increasing efficiency, can results in higher demands for similar product. Thus, increased efficiency for a maximum predictable resource is not attained; the rebound effect decreases, denies, and surpasses the advantages of amended technology-related efficiency. Similar experimental researches have examined direct rebound influences in use of energy in an institutional condition or in different consumer fields for example residential lighting, residential heating, residential cooling, and electricity. For instance, research's studying the rebound effect of fuel prices on vehicle miles travelled (VMT) deduce that direct rebound consequences frequently arise, differing among 10 to 30 percent [Greening, L.A.; Greene, D.L.; Difiglio, C]. However, a considerable number of studies clarified that revolutions in technology could also results in indirect rebound impacts.

They increase when savings in money and time by the technological innovation cause an inclination on consuming other services and goods. For instance, HD television, even though the initial cost is expensive, it might end up with savings in cost as visits to the cinema could be substituted by watching movies through private full HD screen. If indirect rebound impacts are involved in the study, a massive percentage of the efficiency saving may be denied [Schettkat, R.]. Recently, more progressive models aim to consider both the changes in consumer performance and the choice of consumer goods. Consumer's Choice of goods does not fully rely on the efficiency, but consumer's life situation and preferences play a role as well. When selecting their mode choice, drivers have the ability to select different travel modes to meet their mobility desires. researches therefore need to consider the indirect rebound effects that are expected by the changes that will take place in the travel mode choice due to the revolution of self-driving cars. Nevertheless, many attempts are done by the researchers to examine how demands on mobility will vary with the presence of autonomous vehicles. Researches such as Simulation of the replacement of car type used from private cars to autonomous taxis in Berlin conducted by [Bischoff, J.; Maciejewski, M] and The Impact on Mobility Behaviour by Vehicle Automation done by [Trommer, S.; Kolarova, V.; Fraedrich, E.; Kröger, L.; Kickhöfer, B.; Kuhnimhof, T.; Lenz, B.; Phleps, P]. conclude that the extensive use of AVs will rise the number of journeys resulting in minimum 3% to maximum 27% extra trips [Milakis, D.; Van Arem, B.; VanWee, B].

2.6 Influence on demand and travel behavior:

Any study plans to introduce a new technology should investigate the determinants of the adoption process. By considering socioeconomical factors, consumer preference, in addition to social interactions impact the speed of adoption and pathway. Furthermore, AVs offer better travel conditions, personal independence, and may generate significant new demand. AVs will allow segments of the population currently excluded such as (young, disabled and elderly people) to commute from one place to another in more comfortable conditions, more productive, and enjoyable time use. This could alter the perception of value of time by decreasing the time cost of trip, which in turn may generate more trips for longer distances than what normal vehicles do. One of the important advantages provided by autonomous vehicles is their ability to offer equity and access for several currently disadvantaged drivers, for example elderly people and individuals with disabilities. This was considered as a plus for AVs, because improving mobility is related with positive quality of life and health consequences. Yet, in order to be accessible, a shared autonomous vehicles SAVs should be introduced. Taking into account high purchasing cost, SAVs are the most affordable method for individual to access self-driving technology and gain its advantages. AVs will allow people under the age of 18 to drive by them self to be taken to their destination, with or without the company of their parents or other adults. This may resolve many challenges associated with sequencing of activities and trip chaining for parents. Moreover, the parents have the ability now to organize their working hours without considering the time taken to pick the children from home and drop them in the school or vice versa. In addition, AVs could solve some of the disruption of family routine by allowing family members to be together having a family time and conduct different activities during the AV ride.

2.7 Expected negative impacts:

Taking decision in offering AVs is complicated issue and highly convenient mobility choice comes with negative attitudes as well, some of the disadvantages are hard to predict at that moment: loss driving skills and competencies, prevalence of obesity, rely more on machines. Worries reported form the volunteers were manly concerning hacking of systems, Spyware on users, data exchange and transfer with the third party, deprivation from the joy driving, absence of trust in the abilities of autonomous vehicles and their networking. Trimble et al (2014) two out of three sorts of trust (distrust, calibrated trust, and over trust) may affect the use of AVs. In which, calibrated trust (match with individual opinions and system abilities) supports proper application, distrust will lead to disuse, and over trust to misuse, which are equally damaging. After a period of time with no driving activity may result in losing the driving skill, as driving reactions become less efficient and memory fades.

2.8 Similar previous studies done by using SP-survey:

Self-driving cars (autonomous vehicles) are considered as current phenomena, with few numbers of researches testing autonomous vehicles dating before 2013. Studies that were generated in the previous five years are in testing the feasibility and technical sides of AVs, as well as how it is going to affect traffic congestion and safety. Limited research focused on the possible behavioural changes and the underlying enthusiasms to use AVs. Since there are limitation in number of studies introducing different mode choices with AVs, several different sources are observed to look for the primary influences that could affect decisions to procure and use AVs. The bases of public opinion discussed in this paper are public opinion inspections except for KPMG (2013) which is based on a focus group research, and Fraedrich and Lenz (2014) who based the results on analysed online comments. Many frequent negative and positive factors were merged into the recent study.

In general, safety and cost can be supposed as either negative or positive characteristics of driverless cars. People are worried form the costs behind this technology (Caldwell, 2014; Casley et al., 2013; Fraedrich and Lenz, 2014; Howard and Dai, 2014) and so far realize that it has the ability to minimize driving-related costs, such as insurance costs and fuel costs (Accenture, 2011). People are also worried about the safety of AVs, such as the safety concerns related to unused moving AVs, system breakdown, system breeching, (Caldwell, 2014). Nevertheless, they noticed that AVs can considerably minimize the incidence of accidents (Schoettle and Sivak, 2014). Society tends to worry about using self-driving cars and are pleased by being able to switch back to the manual control (Dai and Howard, 2014). Other advantages related to the use of autonomous vehicles include positive environmental impact (Dai and Howard, 2014), increase the value of time (VOT) by decreasing the duration of trips (Accenture, 2011), increasing mobility (Dai and Howard, 2014) and comfortable scale (Fraedrich and Lenz, 2014). Caldwell (2014) had findings stating that there are drivers who simply enjoy driving and consequently they will not go for AVs and be interested in them. concerns about AVs are related to worries regarding legal obligation (Dai and Howard, 2014) and security (Schoettle and Sivak, 2014). Few studies have used choice theory to model several features of AVs. Dai and Howard (2014) created a logit model to determine the influences of a driver's characteristics and local driving behaviour on his opinion about Autonomous vehicles. Boyles and Levin (2015) introduced a nested logit model for mode choice forecast. Choices include the following modes: (a) using AV and parking costs at journey's end, (b) using AV and returning the AV back to its origin (plus a cost for moving), and (c) transit. Megens (2014) performed an SP study in the Netherlands to examine the ideal levels and conditions for automation. Some of mentioned models also observed the impacts of the driver features on their opinion towards autonomous vehicles. Most of the studies deduce that males are more likely to accept autonomous vehicles idea than females (Missel, 2014; Megens, 2014). This tendency of males to obtain driverless cars is also displayed through them by obtaining AVs earlier, having some worries about self-driving cars and assuming that they have a higher level of safety (Casley et al., 2013). (Kyriakidis et al., 2015) stated that males would have fewer concerns toward full automation, in addition to being more willing to purchase full-automation cars. (Payre et al., 2014) mentioned also that men were found to want to obtain and uses AVs more than woman. Furthermore, Kyriakidis et al. (2015) conduct a study which deduce that drivers who travel more distances have the tendency to spend more for self-driving cars. Dai and Howard (2014) raised a question of How often would you use Autonomous vehicle as a taxi? And the study concludes that men with high income, high level of education (minimum with a college degree) and own expensive cars are more willing to use self-driving cars. In addition, people who prioritize safety and amenities among all other vehicle characteristics are more likely to use autonomous vehicles. In this study we investigate the Qatari residence motivations to purchase and use a privately-owned self-driving car or subscribe to use shared AVs among four different mode choices.

Pakusch, C., Stevens, G., Boden, A., & Bossauer, P. (2018). conducted an online questionnaire with 302 volunteers in Germany to analyse the impact of AVs on mobility behaviour and to find out the users preference. The results don not confirm that the enhanced quality of time and higher comfort scale in self-driving cars could lead to a rise in preference of using AVs. In addition, the study detects that the private cars, either fully automated or conventional, will remain the main mode choice. Furthermore, as human behaviour is the reason behind 90% of crashes worldwide, switching from the regular driving mode to full automation mode will result in a significant decrease in incidence of crashing. At the same time the study indicates that the presence of variety of mode choices will negatively influence the public transport, which means that more efforts should be spent for achieving an increased favourability in public transport travel mode if sustainable mobility is to be advanced. However, indirect rebound effects in the form of mode shifts from more sustainable modes such as PT to SAV are to be anticipated.

Brownell and kornhause (2014) define five measures that public transit must achieve for competing with private car ownership. These are 1- competitive travel time, 2- congestion mitigation, 3- safety enhancements over private vehicle use, 4- scale of comfort and convenience comparing with private cars, and 5- better environmental credentials. It is mentioned that these attributes are potentially met by a shared AV network. A demonstrating application is then achieved to compare and evaluate the competency (by investigating the difference in travel costs, travel times, and fleet size) of personal rapid transit (PRT, where passengers are delivered to their destination at taxi ranks) and smart para transit (SPT, a request responsive system). The model adopts that these schemes can assist the total travel request within the state of New Jersey. The results conclude that SPT is more competent than PRT in both costs and fleet size but will have more ride sharing (higher car occupancies). It is proposed that SPT could compete with normal vehicles in comparison with the provided (1^{st}, 2^{nd} ,3^{rd}, and 5^{th}) test criteria, given that reducing the fleet size will allow the use of road capacity more efficiently (hence mitigating traffic jam) than existing systems. Nevertheless, it is recognized that the investigation does not take into considerations whether the SPT system would be comparable with regular car ownership in terms of comfort scale and suitability - particularly the provided records show that SPT needs the rides to be shared which might not be preferable. This is remarked as a main possible obstacle to the acceptance of fully automated driving system.

Fagnant et al. (2015) created a simulation-based model for the possibility of introducing autonomous vehicles in Austin, Texas. And the results showed that approximately all commuters living within a 12-mile by 24-mile space in Austin decided to shift for using driverless vehicle for transportation. This slightly restricts the strength of claims made on the foundation of the simulation. However, it is expected that approximately every autonomous vehicle will take the place of nine conventional private normal cars. As a result, lands that are nowadays used for the keeping private normal cars could be free for using them in other facility services. other than that, full autonomous vehicles were revealed to generate a supplementary 8% of 'empty vehicle' commute that might not occur in the private ownership model.

Schoettle and Sivak (2014) lunched a survey to examine the perception of AVs among a sample of 1533 participants in USA, UK, and Australia. Awareness of self-driving cars was found to be high, with 66% of UK volunteers, 61% of Australia volunteers, and 71% of USA volunteers reporting that they had previously heard about self-driving cars. Overall, a clear undesirable perception of driving less cars among the volunteers was detected in most (not all) of the assessed questionaries' reviewed. This was the similar to the results collected from Cisco (2013) survey which recorded the respondents of 23,450 motorist drivers and found that 65% of participants reported appreciating the joy driving to ever want a self-driving vehicle. Similarly, among 1099 of volunteers in UK, 61% of them reported that they would definitely not consider buying AVs (Adams 2015).

A few numbers of surveys provided more positive attitudes. Sivak and Schoettle (2014) detect that more than 50% of the sample has positive general views of driverless cars and had optimistic anticipation about the possible advantages such as predicting lower harmful gaseous emissions, lower number of crashes, and reduced crash severity. Cisco (2013) surveyed 1514 individuals in 10 different countries. The results revealed that 57% of respondents would use the AVs, with higher magnitudes being recorded in promising markets (for example 95% in Brazil, 86% in India, and 45% in UK). Payre et al.'s (2014) lunched a survey and collect responses of 421 French driver. The study found that around 68% of the responses considered fully automated driving (FAD) being more beneficial than normal driving. In contrast, Kyriakidis et al. (2015) examined the preference of AVs among 4886 international participants through online survey. The results revealed that manual driving is the most pleasant travel mode and FAD is the least pleasant travel mode. This was the overall public perception about driverless cars. Furthermore, Payre et al. (2014) detected if FAD is anticipated to be beneficial. While Kyriakidis et al. (2015) used a different proposition and inspected whether FAD is expected to be pleasant.

Recorded responses to Schoettle and Sivak (2014) questionnaire indicated a high level of concerns regarding loss of access to manual controls, AVs being less safe than normal cars, security regarding data hacking and pertaining to software, and driverless cars commuting while unoccupied. Kyriakidis et al. (2015) observed that volunteers could at the same time admit possible benefits of self-driving cars, while also having concerns about the same features. The survey of 107 potential early adopters clarified that the high safety level and the ability to multi-task were considered as ‘appealing characteristics’ of self-driving vehicles, but participants were simultaneously concerned about their expected loss of control over driverless cars. According to (Casley 2013), males' responses have shown more positive perception of driverless cars compared to females. Missel (2014) reports showed that young individuals, especially those living in urban areas and have no interest in vehicles, were more likely to accept driverless cars as a mode of transport compared to other groups. Casley (2013) detect that volunteers with higher education levels have more concerns about safety of AVs. Kyriakidis et al. (2013) published a paper stating that people with longer experience in driving, commute longer distances, and obtain a higher salary were more willing to purchase AVs than other groups. Payre et al. (2014), examined the connection between behaviors towards self-driving cars and intension to use fully automated driving. They revealed that showing FAD as useful, safe, and enjoyable mode of travel anticipated intention for using FAD. They also agreed that high sensation seeking anticipated the ability to use FAD. The term high awareness seeking is defined here as an attribute to describe the willingness to have complex, varied, novel, and intense feelings and experiences and the tendency for risk taking for the sake of such experience” and this was previously found to be associated with ‘risk-taking behavior. This in somehow designates that fully automated driving currently seems to be considered as a high-risk activity when compared to normal driving. Whether an individual sense will be able to control events that affect the driver (i.e. their ‘locus of control’) was not found to predict purpose to use fully automated driving.

Limited studies have investigated how people predict using level-4 and 5 vehicles without driving. Dai and Howard(2014) revealed that individuals observed the possibility for performing different tasks and not wasting time to find parking lots as one of the main positive points for AVs. However, in Schoettle and Sivak’s (2014) survey 41% of the volunteers were expected to keep on observing the street and this was number one choice in car activity followed by I wouldn't ride in AVs by 22% and reading by 8%. Casley's (2013) study proposed that the likelihood for using travel time efficiently was not observed to increase the motivation for obtaining a Driverless car. Shorter travel time, improved fuel efficiency and environmental credentials of self-driving car system were valued as major advantages.

Cyganski et al. (2014) mentioned that the extent to use journey time efficiently is expected to be an important predictable advantage, although there has been little regular research associated with individual's preference for testing AVs. An online survey was conducted, and more than thousand responses was collected. The questionnaire measures existing travel time usage in addition to the predicted travel time usage for four self-driving cars 'use scenarios': Highway pilot, Full automation vehicle, Valet parking and Vehicle on demand. The questionnaire found that 69% and 77% of users of public transport did not work on long and short destinations respectively. consequently, time spent travelling is only used efficiently by a smaller number of transporting people. In consistence with this result, only 13% of participants were able to predict that they can use travel time for work as a benefit of driverless cars. A probate regression model established that a positive behavior towards effective use of in-vehicle time was related with being male, not having a high yearly car mileage, or having a rail card, using trains and vehicles frequently, having an optimistic insight of public transport and presently using time spent in travelling efficiently. It was also observed to have more useful uses in which self-driving cars were used in urban scenarios.

Malokin et al. (2015) conducted a study to determent the measurements of 'utility' in relation with the capability of using travel time efficiently on public transport and inspected the degree to which this characteristic of self-driving car may induce a change in travel mode choices (towards driverless cars). They lunched an examined preference survey of drivers in California– Sacramento Bay Area transportation corridor (n=2,120). Logit models showed that the capability to work on the mobility in smart cars could possibly lead to another 0.7% of travelers to choose lift sharing and another 0.3% of travelers to choose ‘driving’ only (with citizens quiting mainly on bus, as well as on biking and traveler rail) representing a model shift that would interpret to be important in increasing the number of vehicles on the road. However, it is recognized that the system of autonomous vehicles may include other car access models as well.

Regarding the willingness to pay for FAD, Schoettle and Sivak (2014) revealed that around 57% of the participants reported not being interested in spending more money for full automation car, and about 25% of their participants were able to pay a minimum of 1880$. Likewise, Kyriakidis et al (2015) revealed that approximately (22%) of subjects will not be able to purchase a new full automation vehicle, but a small number of participants (5%) will be able to spend more than $30,000. Payre et al. (2014) revealed that the ability to purchase new vehicle is less than €10,000, with a mean value of €1,624 which is equivalent to $1,835 between the 78% of volunteers (French drivers) that foreseen purchasing a vehicle with automated driving system. Adams’ (2015) demonstrated a UK-based sample of citizens living there, and stated that they have generated an average ability to spend £2,117 (or $3,239) to ‘add self-driving option to their vehicle’. Dai and Howard (2014) detected that more than 60% of survey participants among all nine demographic groups, mentioned the cost as a concern’ and propose that more econometric analysis is needed to set up more robust measures of ‘ability to pay’ for self-driving cars.

Krueger et al. (2016) conducted a stated preference survey (SP-survey) to find out population's travel mode selected options, when challenged with the available amount of a SAV system with or without dynamic ride sharing. The SP-questionnaire was uploaded online and accomplished by a number of 435 volunteers in Australia. With help of prezi software to initiate the idea of SAVs, a multinomial logit model is predicted, on the choice of SAVs that could be shared or used without sharing, or if they would not use SAV for most common trips. The possibility of choosing SAV as mode choice found to be higher if the participants were young in age, presently a multi-modal commuter, or if the work was the traveller destination. The model estimates that around 36% of trips conducted by normal cars could be replaced by SAVs which is consistent with Malokin et al.'s (2015) outcomes, which are distinguished as important and are used as an indicator of the 'disruptive prospect' of SAVs.

In similar research done by Venkatesh V, Morris MG, Davis FD, Davis GB, four important influences are considered as antecedents of user willingness to use AVs and their predicted behavior. The primary antecedent is performance anticipation and refers to the recognized worth of the technology. The next variable is effort expectation, and it represents the level of difficulty the driver will face while using the new system. After that, the social impacts which are altering people behavior towards adoption of a new technology. The Fourth variable is the facilitating conditions such as the infrastructure or support which will encourage the driver to use the new system.

In similar vein, an existing study done by Payre W, Cestac J, Delhomme P, measuring the impacts of psychological antecedents on purchase and usage intentions, found optimistic results for usage intentions between a specimen of 421 French drivers .Their conclusions propose a considerable positive effect on the overall attitude towards self-driving cars, acceptability, and impression (i.e., novelty) looking for usage intentions. Moreover, they found a gender impact showing a higher usage intention for men. A further impact is consistent with existing technology adoption literature, which commonly predicts that male drivers are more likely to be the first adopters.

David M. Woisetschläger, proposed a model which splits into a series of 3 studies and recruited people from an online panel provider who were examined through online questionnaires. The selection of respondents was based on the requirement of having a valid driving licence, owning a private vehicle, and gender and age distinction by German citizens between 18 and 70. Before the manipulation, participants were asked to mention the model and brand of the vehicle that they would use mostly. The results revealed that the respondents on average do not rely on automated driving technologies.

Ricardo A. Daziano,⇑, Mauricio Sarrias b, Benjamin Leard, distributed an online survey which included questiones related to energy efficiency and autonomous features, and more than 1260 responses were collected. Numerous models were appraised with the option of microdata, with a conditional logit with deterministic consumer heterogeneity, a parametric random parameter logit, and a semiparametric random parameter logit. In this study 3 results were recorded. First, they detected that the average household have the ability to purchase a considerable amount for AV: approximately 4900$ for full automation and 3500$ for partial automation. Second, they determined large heterogeneity in predilections for automation, where a considerable share of the people are able to pay more than 10,000$ for advance car levels (level4- level 5 vehicles) while many are not willing to spend any additional expenses for the full automation technology. Third conclusion, the semiparametric random parameter logit results recommend that the need for automation is divided roughly evenly between high, modest and no demand, focusing on the necessity of demonstrating flexible preferences for developing vehicle technology.

Udara Eshan Manawadu∗, Masaaki Ishikawa∗, Mitsuhiro Kamezaki∗∗, and Shigeki Sugano conducted a study to investigate the preference for self-driving system under several traffic environments through a driving simulator. During this study, the group examined the participants driving experience for independent and normal manual-driven vehicles among experienced and beginner drivers under different traffic circumstances. To conduct the experiments efficiently, the group established a basic driving simulator. The team decided to use four different scenarios and six events to distinguish the differences between Self-driving and manual driving modes. Twelve volunteers were split into two groups (six with driving experience and six received their driving license recently) these groups were engaged in the experiments by driving in two driving modes under changed road situations. The groups then assessed the individual driving experiences and preferences for both driving modes. The conclusion illustrated that two of the examined groups preferred self-driving system in both parking lots and urban traffic scenarios. Moreover, the analysis presented that motorists preferred to use both driving approaches, and their choice of mode will depend on the traffic conditions and road environment.

Wenwen Zhang, Subhrajit Guhathakurta, Elias Khalil, conduct a study about the effects of PAVs (Private owned autonomous vehicles) on vehicle ownership and unoccupied VMT generation. The team developed various models to investigate how much reduction in vehicle ownerships can be reached once self-driving cars replace private normal vehicles, and the locative spread of unoccupied VMT are escorted with the reduction in number of vehicles. These models are performed by using travel questionnaire and created trip profile from Atlanta Metropolitan Area. The outcomes demonstrate that around 18.3% of the responses collected from different households mentioned that they have the tendency to decrease their number of vehicles even if they maintain the existing travel schedule compared to 9.5% reduction in vehicle ownership that can be accomplished for the weighted vehicle inventory in the region. It is worth to mention that if the households have the willingness to reduce their number of vehicles, approximately, 1.1 vehicles can be removed in each house. Unfortunately, most of the families cannot give up driving and reduce their number of vehicles given their overlapping trip schedules, particularly during peak hours. It is possible to minimize the number of the cars if household individuals start to re-schedule daily journeys to accommodate self-driving cars. The outcomes also proposed that families with different socioeconomic characteristics have higher likelihood to benefit from private autonomous vehicles. People with higher salary and non-renters (homeowners) are highly willing to decrease vehicle ownership. In addition, families which include more working members are also more willing to decrease the number of owned vehicles in case the cars can reposition from workplaces to be under the service of other households' members in other locations. Furthermore, the results revealed that built environment features are also related with car ownership reduction abilities. The model outcomes recorded that families in suburban areas, which are away from downtown and are less intensively developed, are more capable to decrease vehicle ownership in the future.

Yutong Cai1 and Hua Wang run a study about Investigating user perception on autonomous vehicle (AV) based mobility-on-demand (MOD) services in Singapore by using the logit kernel approach. In a period of four months in 2017 (from September until December) a stated preference survey was distributed through two methods 1- paper based questionnaire in the field, 2- and online soft copy , also a cash grocery vouchers were handled to each participant to improve the quality of the collected information. Thereafter, these data were obtained from citizens living in the Toa Payoh area of Singapore. The overall sample size was 1477 volunteers, 927 did the online survey and 550 responses were collected from the field. The SP-questionnaire was developed to understand the driver's insight towards different AV-based MOD methods being used as first and last mile which can replace the use of existing transportation modes such as walking, cycling, and bus. The questionnaire is composed of three parts. With the fist component being about demographic data, second one about qualitative preference questions toward use of self-driving cars, and third one includes scenario tests. A logit kernel model was chosen to investigate the demographic indicators and the key performance attributes that can affect AV-based MOD use. Based on the obtained results in this study, numerous main observations can be summarized in the following points:

1- Transit users represent 31% of those who prefer switching to AV-based MOD services and approximately around 57% of the respondents were willing to use AV-based MOD connection services with mass rapid transit.
2- old male drivers with low education level, high monthly income, and weak value for convenience tend to go for AV-based premium and economy MOD service. On the other side, younger female drivers with higher awareness of ride hailing apps and higher educational level prefer the use of self-driving cars as their first and last mile mode of transport. The most effecting factors in the choice making was the travel time, cost, and predicted delay in the driver branch.
3- Male transit users with lower education level, public housing, higher monthly income, and poor value for convenience were found to have a higher interest for

privacy and lower interest in self-driving cars which shows that they have higher tendency to choose AV-based economy MOD services. Moreover, elderly female transit user with higher education level, private housing, and higher monthly income were also found to have higher preference to accept AV-based premium and sharing MOD services.

4- Drivers exposed to the use of ride sharing app have the ability to use the AV-based premium MOD services.

5- Because of the weak performance in the major determinants which are cost, predicted delay, and travel time, sharing based AV MOD services are not well known between drivers and public transport users in Singapore.

CHAPTER 3: METHODOLOGY

Since that self-driving cars are not readily available, a stated preference survey is designed to find out about Qatari citizens preferences among different modes of transport. Firstly, this section will discuss the process of designing the questionnaire used to collect the people responses, followed by SP-scenarios to predict the preferred mode choice among different transport alternatives. The SP-scenarios include five attributes which are: purchase cost, annual subscription cost, travel cost, travel time, and comfort scale. Purchase cost is the price of either normal car or private autonomous vehicle. Trip cost is how much is going to cost the user to reach the desired destination, and it includes the fuel cost, depreciation cost, and maintenance cost in case of the normal car. While trip cost is the fuel cost in case of normal vehicles and fuel cost plus interest in case of using other alternatives. Subscription cost per year is a subscription-based pricing model that has a payment structure which allows the customer or organization to purchase or subscribe to a transport services for a 12 months period for a set price. In general, subscribers typically commit to the services on monthly or annual basis. Average trip duration is the average travel time to commute from a place to another within a 20km distance. the reason behind choosing this distance because 20km is considered as a long commute trip connects two far points in Qatar. in addition, 20 km was chosen as the drivers will have to pass through several crowded places within different conditions in a one trip. So, they will think carefully before choosing any of the four modes of transport in the SP-scenarios part. Finally, there is a comfort scale for each of two options (good, bad) and it represents the evaluation of comfort experienced by both drivers and passengers while using different transport mode choice. Moreover, the hypothetical alternatives used in SP-scenarios were four: normal passenger cars, private autonomous vehicle, shared autonomous vehicle, and public transit. A private autonomous vehicle is the privately owned high functional car which can drive itself from a starting point to a predetermined destination. Whereas shared autonomous vehicle is the high functional car which requires the customer to subscribe to share the autonomous vehicle system, so that the customer not own the vehicle but have access to use the autonomous vehicle whenever required. Last is the public transit, and it refers to the use of public buses and metro. Nevertheless, the questionnaire is prepared to be capable of developing immersive, interactive, highly realistic, and associated infrastructure changes on urban streets in Qatar. Moreover, the idea behind the Automated driving transport system (ADTS) could be impartially presented to volunteers who had not experienced AVs. One of the advantages of ADTS adoption might be the opportunity of transferring mobility from an ownership-model, as in the case of a private vehicle, to an on-demand service. Acknowledging that questionnaire respondents have not experienced self-driving cars, a stated preference experiment was used for the data collection strategy. It is preferable that attributes and attribute levels in the stated preference experiment are based on real situations to which participants could easily recognize. In which the estimated travel time include the time spent inside the vehicle only. The instructions were written with care to make sure the participant would be able to visualize the conditions as much as possible, given the nature of an SP experiment. This part of the thesis includes the design of the survey used to gather the data, plus the model design to estimate the choice between four mode of transport.

3.1 Survey design:

The SP- questionnaire was distributed online using a well-designed website with adobe animation platform in a four months period (June-September 2019). Examining questions were targeting only adults greater than 18 years old with driving license who drive for the commute to university or work. While data collection was proceeding, the questionnaire was distributed among the participants in Qatar. The link of the website was shared through social media such as Facebook and Instagram. Upon the completion of the survey, each participant will have the chance to win a 100 QAR Coupon. Several coupons were randomly distributed to participants who successfully completed the survey. Successful winners will be contacted via email, after closing the surveying to collect their coupons. Moreover, the data was checked by eliminating those participants who did not fully complete the questionnaire. More than 300 volunteers completed the survey, each provided a response to 6 scenarios, resulting in a total of more than 1800 usable observations.

The survey consisted of 5 parts:

1- First part consists of Socioeconomic questions to collect important information about the characteristics of the participant. This part includes age, gender, type of employment, salary of the individual, education level, and family situation.
2- Second part includes driving habit questions. The asked question in this section is necessary for understanding the factors which effect the choice of AVs. The values observed from this section will be used in mathematical formula for creating SP-scenarios in the last part of the survey.
3- Third part includes attitudinal questions about AVs to observe attitudes that could affect the preference of the self-driving cars. The third part made of three

subsections with series of 14 statements to which the volunteers were asked to indicate their level of agreement by choosing one of the following five choices (strongly agree, agree, neutral, disagree, and totally disagree). The 14 statements examined how much respondents know about AVs, attitudes toward car safety, attitudes toward car features, and attitudes toward environment.

4- Fourth part includes questions related to travel behavior and mode choice. This part plays an important role in indicating how travel time, travel cost, and travel distance will influence preferences of AVs.

5- Last part of the SP-survey is made of 6 stated preference questions to gain insight into the travel mode choice of the participant. The volunteers were exposed to a series of 6 different tables similar to one found in table 1, provided with values within the table changing in each scenario. The values depend on the individual responses in the previous four parts.

Table 1. variables presented in SP choice tables to participants

Purchase cost (QR)	Subscription cost/ year (QR)	Trip Cost (QR)	Travel Time (Min)	Comfort scale	Alternatives
30000	-	23	40	good	Car_Normal
30000	-	24	48	poor	AV_Owned
-	8100	0	52	good	AV_Shared
-	2000	-	80	poor	Public_transport

3.2 SP- Scenario design:

It is important to mention that the scenarios were generated to test five attributes within four mode of transport. The SP- scenarios compare between the following Travel modes:

1- **Normal vehicle:** passenger car
2- **Private autonomous vehicle:** is the privately owned high functional car, which can perform an automated driving from a starting point to a predetermined destination.
3- **Shared autonomous vehicle:** it is the high functional car which requires subscription to share the autonomous vehicle system, in which you do not own the vehicle but have access to use the autonomous vehicle whenever is needed.
4- **Public transit:** which includes both Metro and public buses and their use.

Moreover, The SP-scenarios includes the following attributes to compare between the travel modes:

1- **Purchase cost:** is the price of the car
2- **Subscription cost per year:** In a subscription-based pricing model, a customers or organization are allowed to subscribe to a transport services for a period of time, which is commonly 12 months period. In general, Subscribers typically commit to the services on a monthly or annual basis.
3- **Trip cost:** how much is going to cost you a trip of 20 KM length, which is equivalent to the distance from Qatar University to Hamad International Airport. It includes the fuel cost, depreciation cost, maintenance cost, and parking cost.
4- **Average trip duration:** average travel time to commute from a place to another within a 20km distance, which is equivalent to the distance from Qatar University to Hamad International Airport.
5- **Comfort scale for each of two options (good, poor):** the evaluation of comfort experienced by both drivers and passengers while using different transport

mode choices. In the case of public transport and shared AV, it meant uncomfortable in the presence of other individuals, stopping at several points, and a possible detour in the case of shared AV. For private vehicles and private AV, it meant smoothness of the ride (i.e. there are not several unnecessary start and stops), software issues in AV, regular/other vehicles in the traffic stream causing safety hazards.

Tables 2 explains the ranges or levels of the attributes used in the scenario design. Furthermore, Table 3 defines the parameters used in setting the different levels of the attributes.

Table 2. Levels of the attributed used for the scenario design of the SP survey

Mode of transport	Purchase Cost	Subscription Cost/Year	Trip Cost	Avg. Trip Duration	Comfort Scale
Car (Normal Passenger Vehicles, already owned)	100%	-	(100%, 120%, 80%) of c	(100%, 120%, 80%) of e	good, poor
AV (Privately Owned, will buy or shift to AV)	(100%, 150%, 250%) of a	-	(100%, 120%, 80%) of d	(100%, 120%, 80%) of e	good, poor
AV (Shred Autonomous)	-	(50%, 100%,150%) of b	(0%, 100%, 200%) of d	(100%, 130%, 160%) of e	good, poor
PT (Metro + Bus), will shift to Metro when it is operating	-	1500 QR, 2000 QR	3QR, 5QR, (it will not be shown to respondent when subscription cost/year will be shown)	(100%, 150% ,200%) of e	good, poor

Table 3. Definition of the parameters used for defining the levels of attributes in the scenario design of the SP survey

Parameter	Value	Definition	Notes
a	mid-interval	Avg. cost of vehicle (given)	Mid interval of the selected answer among the five choices in Part B question B4 (for example if the participant chose the first answer which is 20,000-40,000 then the mid-interval =30,000)
b	5400 QR	Avg. subscription cost per year (given)	A subscription-based pricing model is a payment structure that allows a customer or organization to purchase or subscribe to a transport services for a 12 months period for a set price.
c	23 QAR	based on given per km cost of car, trip distance is required to be known	Average trip cost by using normal car considers it equivalent to 20KM × 1.16 QR/KM = 23 QR
d	30 QAR	based on given per km cost of Av's	Average trip cost by using Autonomous vehicle is 20KM × 1.5QR/KM = 30 QR
e	40 min	avg. time based on distance	Consider it equivalent to 40 min which will be the average travel time to reach a 20KM destination let's say from (Qatar university to Hamad international airport)

Furthermore, as clarified in previous tables the purchase cost was made with one level in normal car and 3 levels in privately owned AV, subscription cost was made with 3 levels in shared AV and 2 levels in public transport, 3 levels were used for trip cost in normal car, privately owned AV and shared AV, and 2 levels were used in public transport. Moreover, 3 levels were used in average trip duration for the four modes of transport and two levels were used in comfort scale factor for the same four modes of transport. However, a SAS procedure MKTEX and CHOICEEFF were used to display the efficiency of the design. The relative d-eff provided by SAS output was around 86%, which seems to be acceptable for this complicated case. For perfect orthogonality, it is desirable to have a 100% efficiency, and the analysed result was close to that using only the 36 scenarios as shown in the following table.

Table 4. SAS output results

Design Number	D-Efficiency	A-Efficiency	G-Efficiency	Average Prediction Standard Error
1	100.0000	100.0000	100.0000	0.2635

The SAS System

Final Results

Design	**31**
Choice Sets	**36**
Alternatives	**4**
Parameters	**9**
Maximum Parameters	**108**
D-Efficiency	**30.9373**
Relative D-Eff	**85.9370**
D-Error	**0.0323**
1 / Choice Sets	**0.0278**

Figure 2. SAS output results

CHAPTER 4:DATA COLLECTION:

The online questionnaire was uploaded on the owned domain website and performed from the beginning of July 2019; grocery vouchers are given for several participants to enhance the quality of the data obtained. In addition, this online survey was uploaded with two languages, English and Arabic (main languages used in Qatar) to receive more and better responses. A total of 315 completed responses were received. It is worth noting that the online survey was sent to people living in Qatar from different age groups and nationalities. The participants were selected from Qatar University and other industries such as Khatib & Alami Consultant Company, Mowasalat Driving school academy, and ministry of public health. It is important to mention that once the data has been collected, the researcher must make sure that the observed responses are clean, formatted, and corrected before using it for the analysis purposes.

4.1 Data preparation:

In order to achieve the objective of the study, it is necessary to apply the following steps:

a- **Data screening:** once the observed data has been entered it is important to check the arrangement and accuracy of the data. Data screening can be achieved by using manual observation and statistical analysis. The goal of this step is to check both:

- **the consistency of data:** by making sure all relevant fields are available and respondents provided reasonable answers.
- **The amount of time spent by each participant on the questionnaire:** in this part it is observed that the average amount of time spent on this questionnaire by each participant in Qatar was between 15 and 20 min which is considered as a considerable time. It is worth to mention, that the amount of time needed by each participant to finish the online SP-survey depends a lot on the education level and his/her background about the asked subject.

b- **Data treatment:** It is about the explanation and resolution of the troublesome data points and patterns. Faithfully, the appropriate choices to solve these problems are limited to correcting, deleting, or unchanging the data. Hence, the decision regarding the choice of option depends upon the nature of data and the problem. In this study, the uncompleted response, strange patterns and inconsistencies data was deleted.

4.2 Data characteristics:

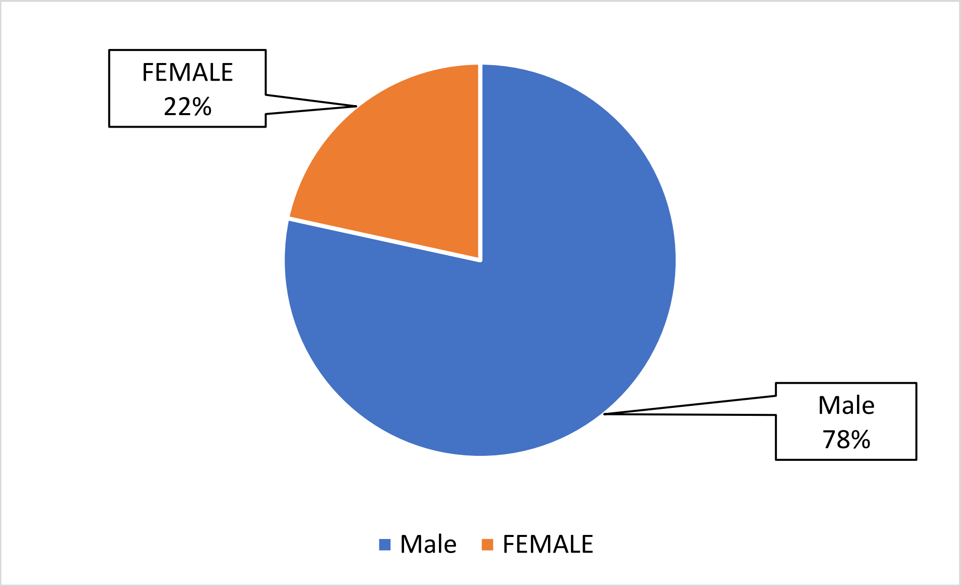

Figure 3. Gender characteristics of the collected sample

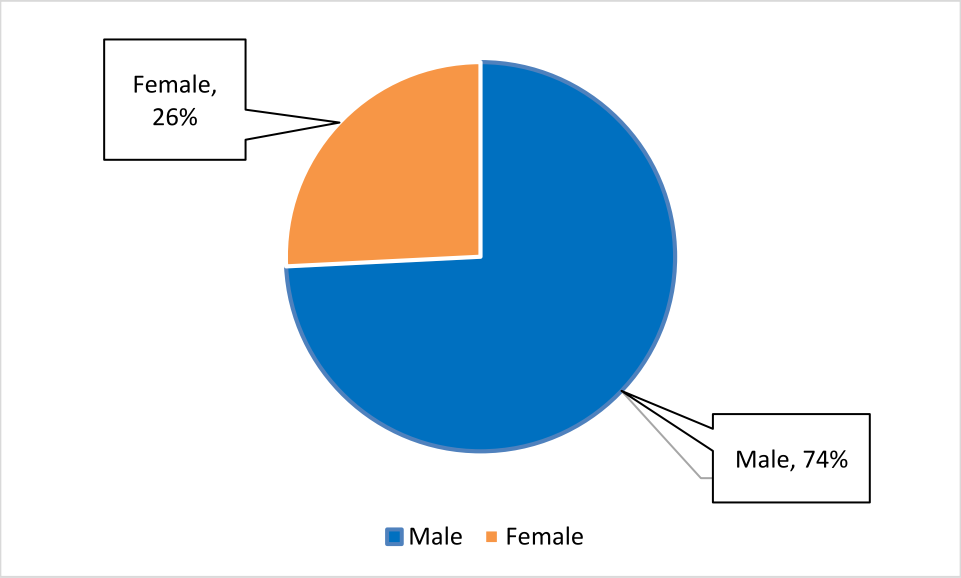

Figure 4. population distribution in state of Qatar in 2018 in term of gender. Based on the statistics report for the year 2018 for the Planning and Statistics Authority

As shown in figure 3, the collected sample of drivers in this study consist of 247 male (78% of the sample) drivers and 68 female drivers (22% of the sample) with different origin and age, ranging from 18 to above 50 years old with an average age of 35. The driver's nationality was divided into eight regional origin categories, as shown in the following Figure 5. If we compare the gender characteristics of the examined sample with the overall gender population distribution in state of Qatar provided in Fig 4. It is obvious that the tested sample is in accordance with overall Qatari gender distribution.

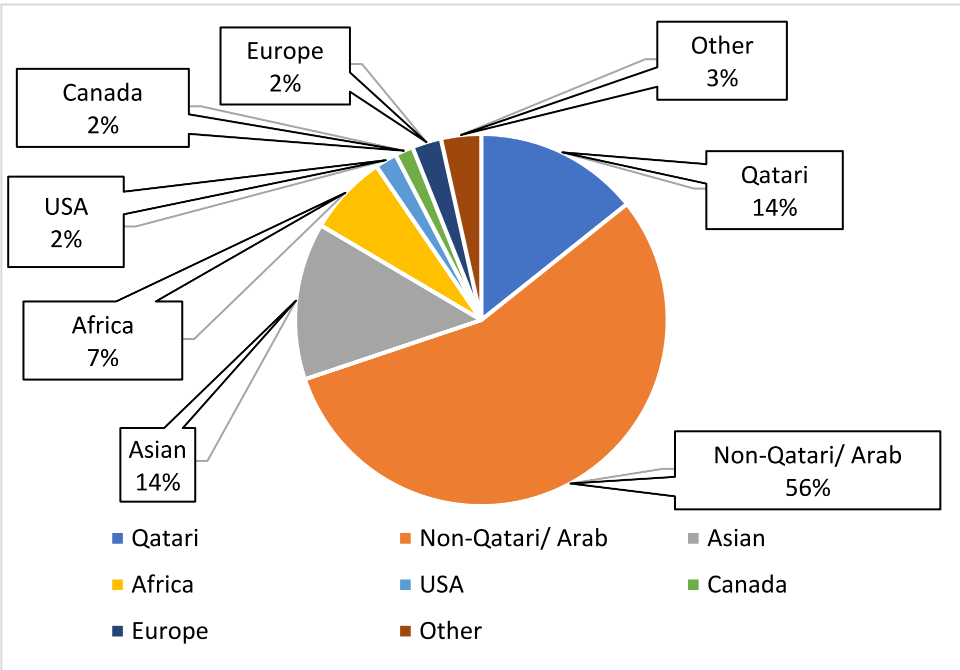

Figure 5. Distribution of nationalities in the collected sample

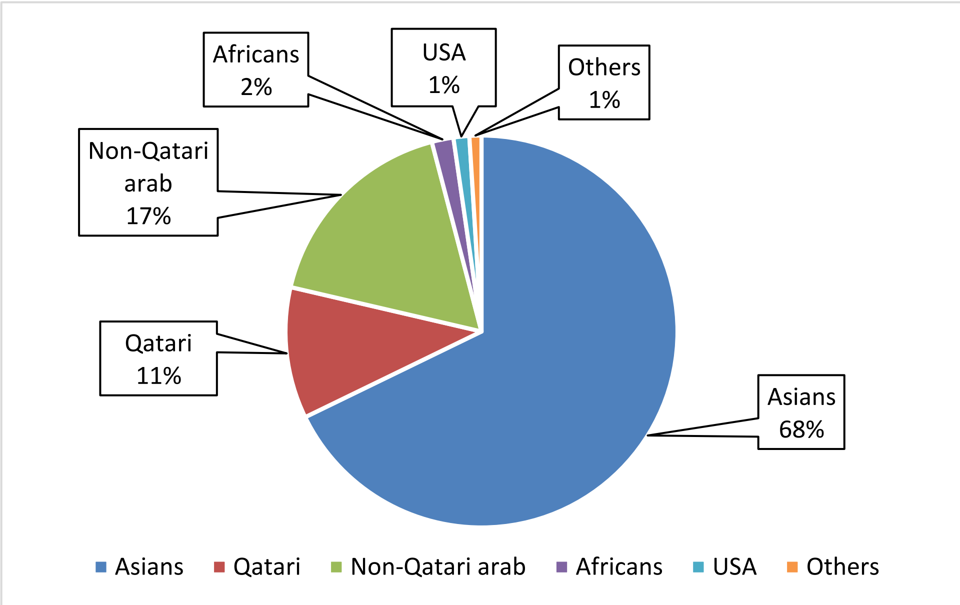

Figure 6. population distribution in the state of Qatar in 2018 in term of ethnicity. Based on the statistics report for the year 2018 for the Planning and Statistics Authority

The number of Qatari drivers who completed the survey was 45 individuals, representing 14% of the total respondents. While Arab drivers who completed the questionnaire were 175 individuals, and they represent 56% of the total respondents. Asian drivers were around 14% of the sample with most of the nationalities from Philippine, India, Pakistan, Iran, Sri Lanka, Nepal and Bangladesh. The majority of the African drivers with nationalities from Uganda, Eritrea, Kenya, Tanzania and Sudan, represent approximately 7% of the sample. The rest of the participants nationality was from USA 2%, Canada 2%, Europe 2%, and others (Australia, South Americans) 3%. After reading the Ethnicity distribution provided by figure.6, it is confirmed that the nationalities of the collected sample are almost following the demographic nationalities distribution of Qatar in case of Qatari, Africans, USA, Canadian, and European nationalities. The Non-Qatari Arab and Asian responses are overrepresented and underrepresented respectively in the collected sample. The purpose behind underrepresenting the Asian responses is because most of them are low income labors with low education level. In addition, many of them refused to participate in doing the survey due to their limited background about AVs. There are five different age groups participated in doing the survey, the majority of the participants are from two age groups, those aged under 24 years old and people 30-40 years of age. Middle age people 40-50 years of age ranked the second place with 21% of the overall responses. The least responses collected was given by elderly age group (people above 50 years old) as clarified in Figure 7. Furthermore, Figure.8 indicates that the distributed percentages of all age groups participate in doing the survey are almost similar to the age population distribution in Qatar.

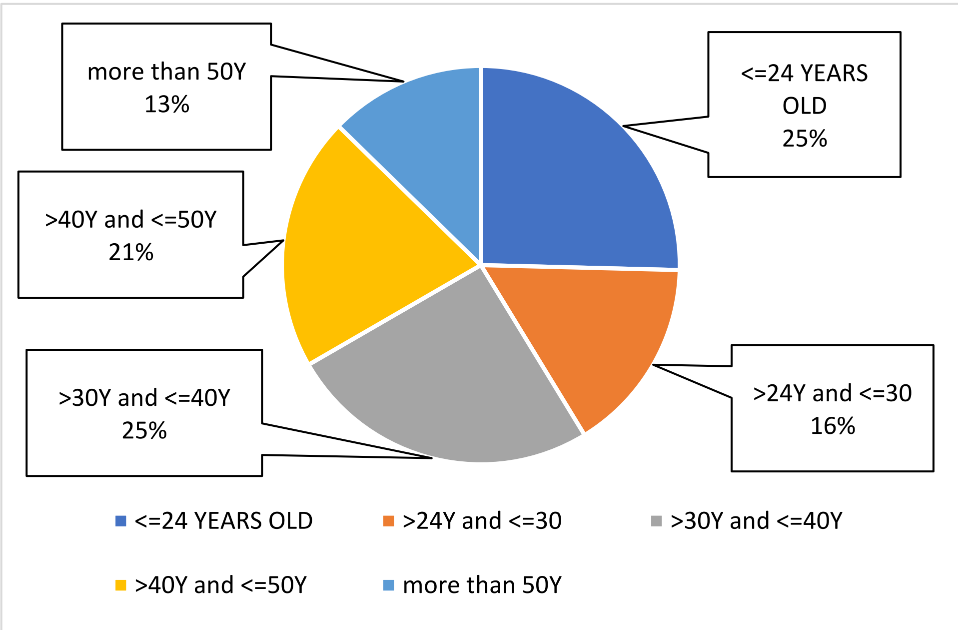

Figure 7. Age distribution of the collected sample

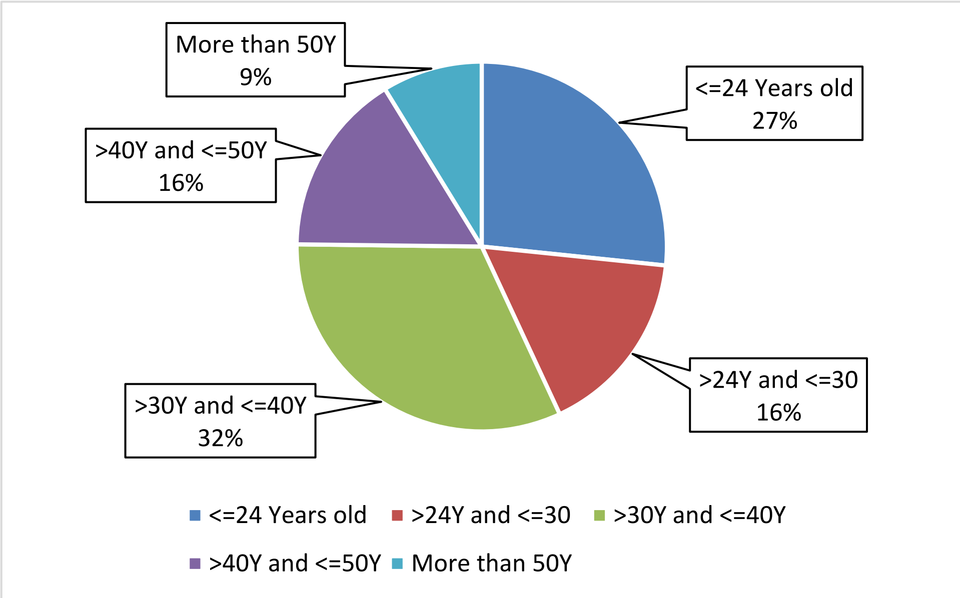

Figure 8. age population distribution in state of Qatar in 2018. Based on the statistics report for the year 2018 for the Planning and Statistics Authority

Regarding the highest education level as shown in Figure 9, the majority of the volunteers hold a bachelor's degree with percentage equivalent to 52%. People with high school degree or lower, came in the second place with 20% of the overall sample. The third place ranked by graduate participants with master or PHD degree. Furthermore, the least percentage was volunteers with diploma degree which represent around 10% of the sample.

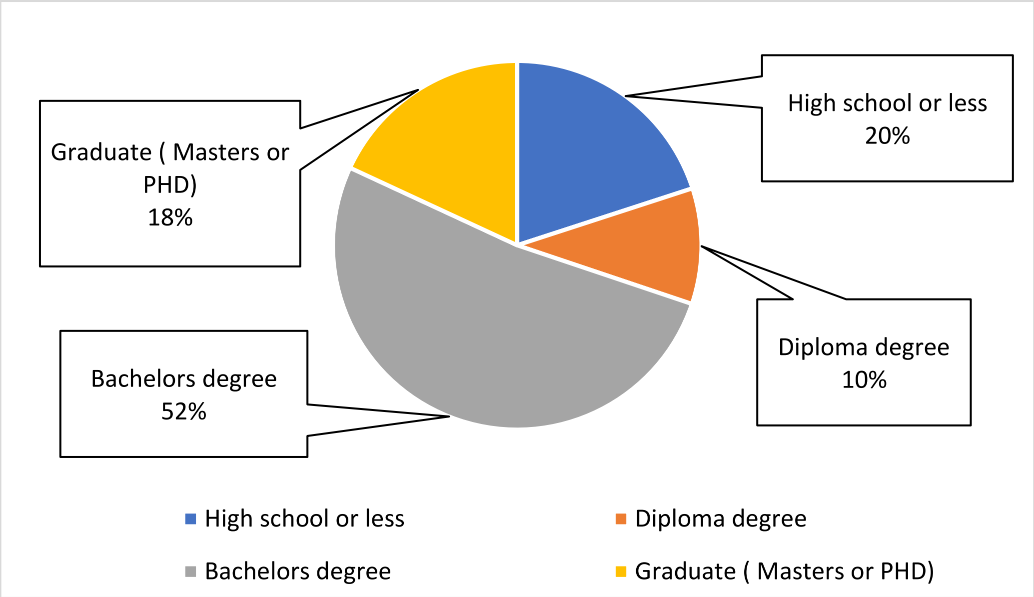

Figure 9. Highest education level distribution of the collected sample

CHAPTER 5: MODEL AND ANALYSIS

5.1 Descriptive analysis:

A descriptive analysis was performed initially on, socioeconomical section of the stated preference survey, in order to gather an idea of the characteristics of participants who did the questionnaire in Qatar. The second section of the survey reveals the driving habit of the collected driver's sample, who also analyzed using descriptive analysis. The third and fourth part of the survey was related to some questions related to autonomous vehicles, travel behavior and mode choice. The last part was related to SP-scenarios. However, by comparing the five sections this study investigates whether there is a relationship between the driver's characteristics in the first four parts of the SP-survey and the chosen mode of transport in the last section of the SP-survey. For instance, Qatar has a very heterogeneous driver population with different nationalities. For that purpose, this study investigates whether there is a connection between the chosen mode of transport and nationality of the participant. Moreover, there was a number of responses collected from KARWA professional driving school from both taxi and bus drivers, making the study interesting to examine the preferences of self-driving cars between KARWA and other drivers. The results gathered from this study is summarized in the visible table below:

Table 5. Drivers sample characteristics

Driver sample characteristics (N=315)			
Driver characteristics		N	%
Language	English	233	74.0
	Arabic	82	26.0
Age groups	<=24 YEARS OLD	80.0	25.4
	>24Y and <=30	50.0	15.9
	>30Y and <=40Y	80.0	25.4
	>40Y and <=50Y	65.0	20.6
	more than 50Y	40.0	12.7
Gender	Male	247.0	78.4
	FEMALE	68.0	21.6
Nationalities	Qatari	45.0	14.3
	Non-Qatari/ Arab	175.0	55.6
	Asian	43.0	13.7
	Africa	22.0	7.0
	USA	6.0	1.9
	Canada	5.0	1.6
	Europe	8.0	2.5
	Other	11.0	3.5
Marital status ?	Single	122.0	38.7
	Married	82.0	26.0
	Married with children	111.0	35.2
Type of employment	Full time employee	214.0	67.9
	Part time employee	18.0	5.7
	Student	55.0	17.5
	Unemployed	11.0	3.5
	Houswife	10.0	3.2
	Other	7.0	2.2
Highest education level	High school or less	63.0	20.0
	Diploma degree	32.0	10.2
	Bachelors degree	163.0	51.7
	Graduate (Masters or PHD)	57.0	18.1

Driver sample characteristics (N=315)			
Driver characteristics		N	%
Average income per month	NA	74.0	23.5
	< 5,000 QR	46.0	14.6
	5,000-10,000 QR	49.0	15.6
	10,000-20,000 QR	61.0	19.4
	20,000-40,000 QR	55.0	17.5
	More than 40,000 QR	30.0	9.5
Number of individuals (including yourself) above 18 years old in your household	1.0	54.0	17.1
	2.0	81.0	25.7
	3.0	54.0	17.1
	4.0	49.0	15.6
	5.0	32.0	10.2
	More than 5	45.0	14.3
Total number of cars in your household	None	27.0	8.6
	1.0	67.0	21.3
	2.0	88.0	27.9
	3.0	54.0	17.1
	4.0	34.0	10.8
	More than 4	45.0	14.3
Number of years of driving experience	0.0	30.0	9.5
	1.0	12.0	3.8
	1-4Y	26.0	8.3
	5-9Y	76.0	24.1
	10-20Y and more	171.0	54.3
Do you own a car	Yes	255.0	81.0
	No	60.0	19.0
Average traveled distance per year	<10,000 KM	61.0	19.4
	10,000- 20,000 KM	94.0	29.8
	21,000- 30,000 KM	80.0	25.4
	31,000- 40,000 KM	43.0	13.7
	>40,000 KM	37.0	11.7
How Much you are willing to pay to buy a new car	20,000-40,000QR	109.0	34.6
	40,000-80,000QR	72.0	22.9
	80,000-160,000QR	82.0	26.0
	160,000-320,000QR	42.0	13.3
	More than 320,000QR	10.0	3.2

Driver characteristics (N=315)			
Driver characteristics		N	%
How much did you know about AV	First time I heard about it	85.0	27.0
	A simple background from (social media, newspaper or internet)	160.0	50.8
	A good background (know some of its properties)	47.0	14.9
	A strong background (know what kind of technology are used in AV)	23.0	7.3
Select one statement representing your perception on the safety of AV	I have no concern about AV safety	51.0	16.2
	Generally, AV are safe, but I have minor concern that something could go wrong	124.0	39.4
	I need to know a lot about AV and their safety perforce	98.0	31.1
	I am opposed of using AV, unless I can override the control manually	28.0	8.9
	I think AV are not safe and should not be allowed	14.0	4.4
For what purpose you travel most by car (work, shopping, social, escort)	Work	179.0	56.8
	Shopping	27.0	8.6
	Social	65.0	20.6
	Others/Escort	15.0	4.8
	I don't have a private car	29.0	9.2
In average how many kilometers you travel per work trip	Not applicable	41.0	13.0
	5.0	32.0	10.2
	10.0	46.0	14.6
	15.0	48.0	15.2
	20.0	60.0	19.0
	25.0	22.0	7.0
	30 and more	66.0	21.0
In average what is the total travel time per day that you commute from home to work (only answer if you use a private car otherwise skip this question)	Blank	36.0	11.4
	Less than 10 min	31.0	9.8
	10-20min	64.0	20.3
	21-30min	77.0	24.4
	31-40min	53.0	16.8
	More than 40min	54.0	17.1

Driver characteristics (N=315)			
Driver characteristics		N	%
What mode of travel do you mainly use for daily commute	Private car (driver)	208.0	66.0
	Private car (passenger)	64.0	20.3
	Bus	21.0	6.7
	Walk	13.0	4.1
	Bicycle		0.0
	Metro	2.0	0.6
	Taxi	7.0	2.2
Would you switch to use autonomous vehicle if both regular and autonomous vehicle have the same travel time and travel cost	Yes	193.0	61.3
	No	122.0	38.7
If you don't own a driving license yet, or not able to drive (elderly/person with disability), or currently use other mode choice such as (public transport or taxi) would you switch to use autonomous vehicles?	Yes	244.0	77.5
	No	71.0	22.5
If you own an autonomous vehicle, how would your travel distance change compare to your current travel patterns	No change	75.0	23.8
	Slight increase (10-20% more)	73.0	23.2
	Moderate increase (20-50% more in distance)	68.0	21.6
	Considerable increase (50%-100%)	21.0	6.7
	Significant increase (at least 2 times more)	7.0	2.2
	Blank	71.0	22.5
Overall, after considering the advantages & disadvantages of using autonomous vehicles, would you shift to use autonomous vehicle	Yes, I would use autonomous vehicle	200.0	63.5
	No, I would not use autonomous vehicle	115.0	36.5

Survey showed that there are variations in income, where 19% of the volunteers earns between 10,000 QR and 20,000 QR, 17% of the volunteers earns between 20,000 QR and 40,000QR, 16% of the participants earns between 5,000 QR and 10,000 QR, 15% of the participants earns less than 5,000 QR and around 10% of the volunteers earns more than 40,000 QR. However, around 23% of participants didn't provide any information about their salary by choosing "non-applicable" choice (NA) as this all data is clarified in Figure 10. regardless that the conventional car is the preferred transport mode choice among Qatari citizens with different income levels, this study revealed that the higher the income of the individuals the higher the possibility to use PAVs and that individuals with monthly income less than 5,000QR have a higher tendency to use public transport PT compared with other categories as represented in Figure.11

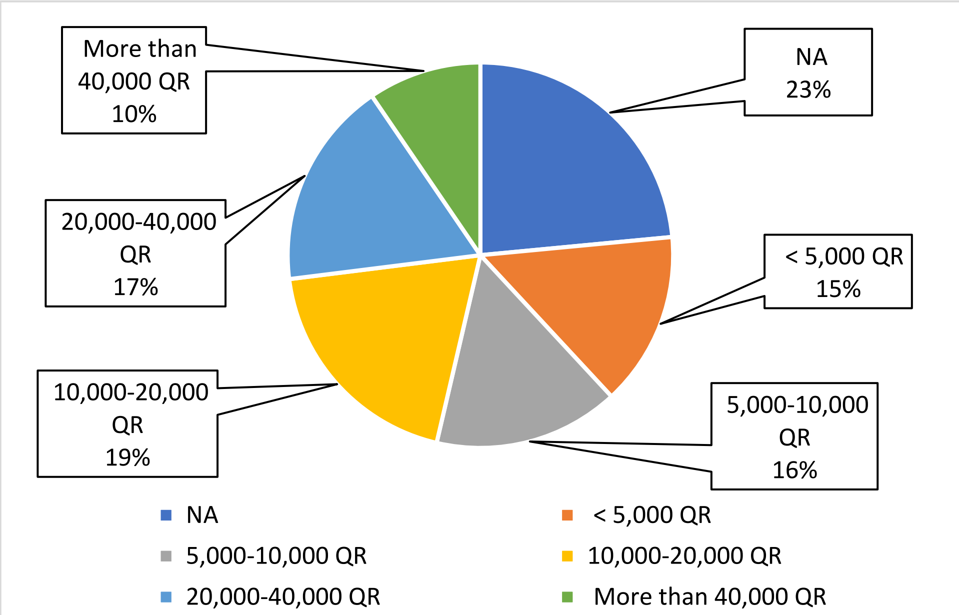

Figure 10. Distribution of average income of the collected sample

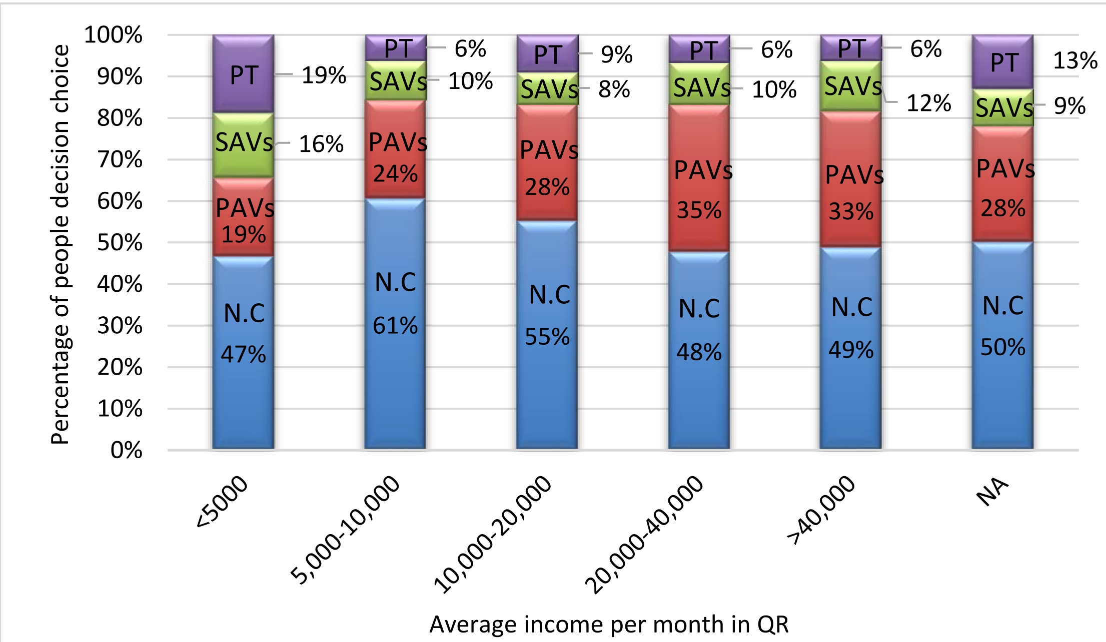

Figure 11. Influence of income salary on the choice decision.

Likewise, it is important to examine the relation between the average traveled distance and the choice decisions of the respondents. A pie chart of average traveled distance per year is visible in Figure 12, with a vast majority of 30% of drivers commute between 10,000KM and 20,000KM per year, 25% travel more than 21,000KM and less than 30,000KM per year, 19% less than 10,000KM per year, 14% of the sample drive between 31,000KM and 40,000KM per year, and 12% of the drivers participate in doing the survey travel more than 40,000KM per year. From the details provided in figure. 13 it is obvious that people who travel more than 40,000KM in Qatar have a higher tendency to use PAVs compared to other groups of travelers.

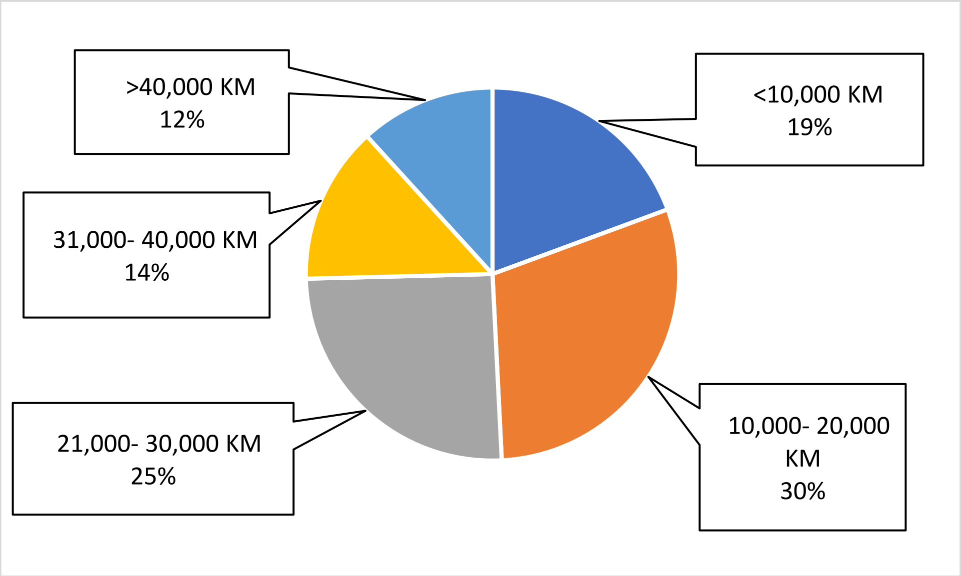

Figure 12. Distribution of average traveled distance per year of the collected sample

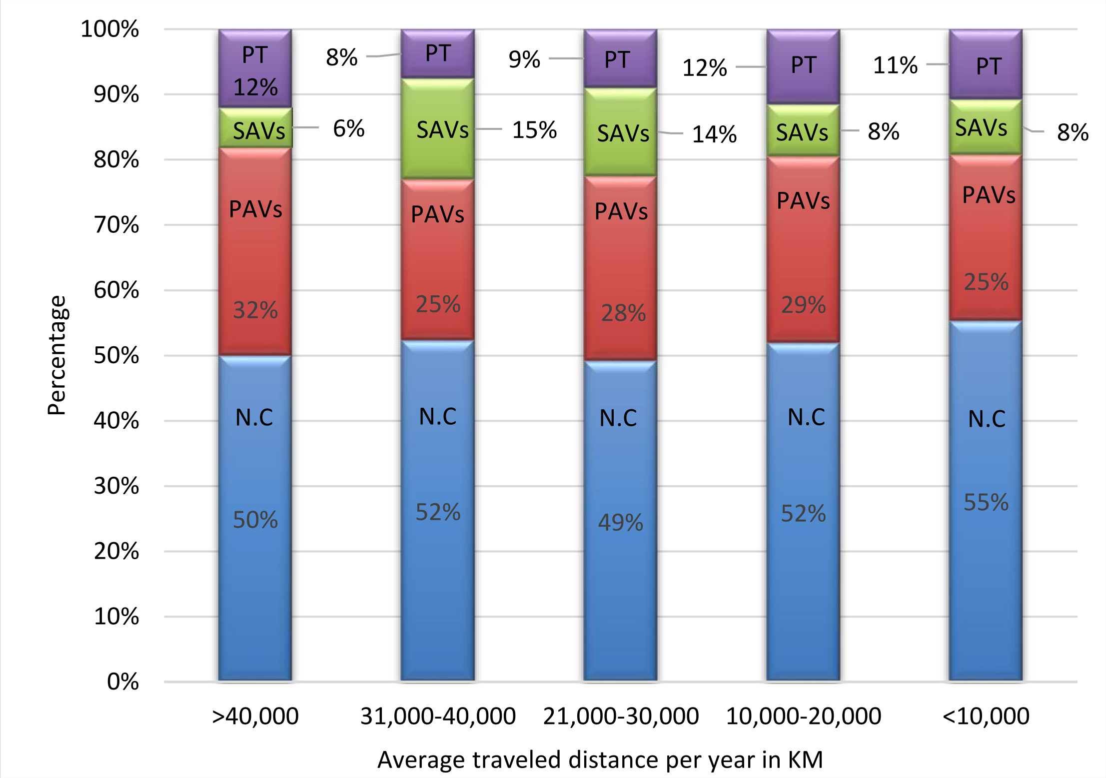

Figure 13. Influence of average travelled distance per year on choice decision

Another interesting trend shown in Figure 14 present how much the Qatari residents are willing to pay for a new car. The importance of investigating such a factor is to determine the effect of the purchase cost in selecting any of the provided four modes of transport. The following figure revealed that around 35% of the participants are willing to pay less than 40,000QR and they represent the majority, 26% have the ability to purchase a car with a price between 80,000QR and 160,000QR, approximately 23% can buy a new car with price between 40,000QR and 80,000QR, 13% of the respondents are willing to buy a new vehicle with a price of more than 160,000QR and less than 320,000QR, only a few percentage equivalents to 3% answered that they have the ability to purchase a new car with cost of more than 320,000QR. Moreover, Figure. 15 clarify the relationship between the average monthly income and the purchasing power in the collected sample. The results obtained from Figure.15 can be summarized as following:

- People with higher income are willing to pay more to own a private vehicle.
- 67% of the respondents with low income (less than 5,000 QR/month) mentioned that they cannot purchase a car will cost more than 40,00QR.
- The majority of participants who receive more than 40,000QR/month stated that they are willing to purchase a car worth 160,000QR-320,000QR.
- people who receive monthly income between 20,000QR/month and 40,000QR/month prefer cars which cost a price that ranges between 80,000QR- 160,00QR.
- As shown in Figure.15, only two categories can afford cars that worth more than 320,000QR. the two aforementioned categories include people that have an income salary higher than 20,000QR.
- Most of the middle-income people who receive between 10,000QR and 20,000QR are willing to purchase a car that costs in a range of 40,000QR to 80,000QR.

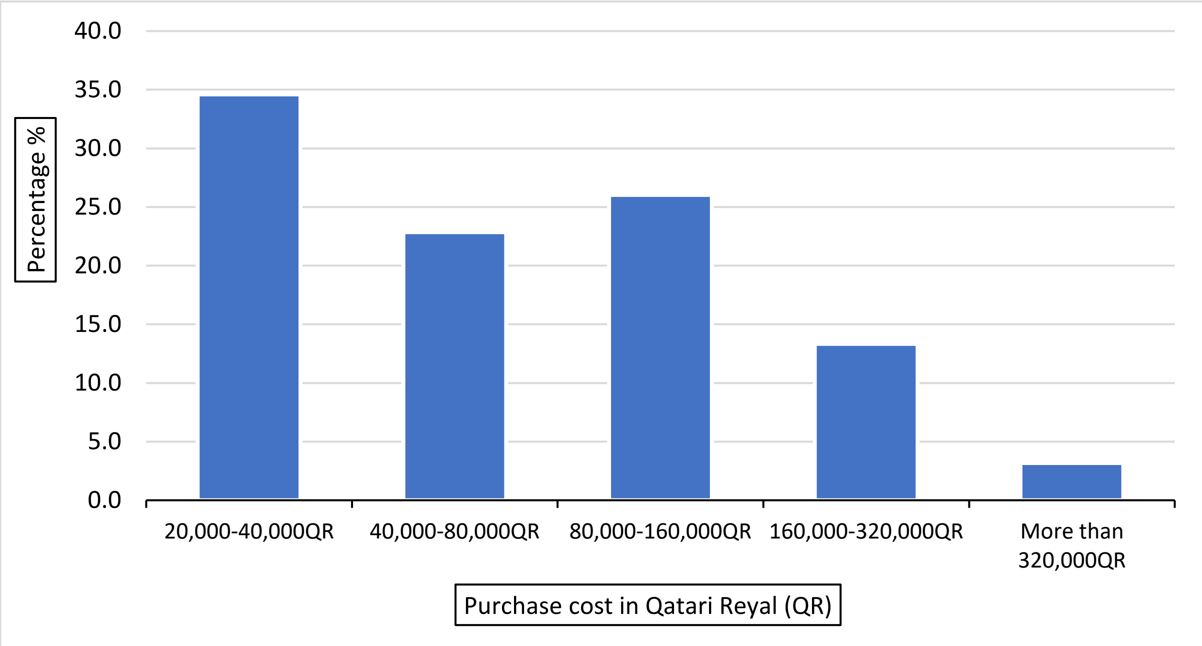

Figure 14. Distribution of participants willingness to pay for AVs

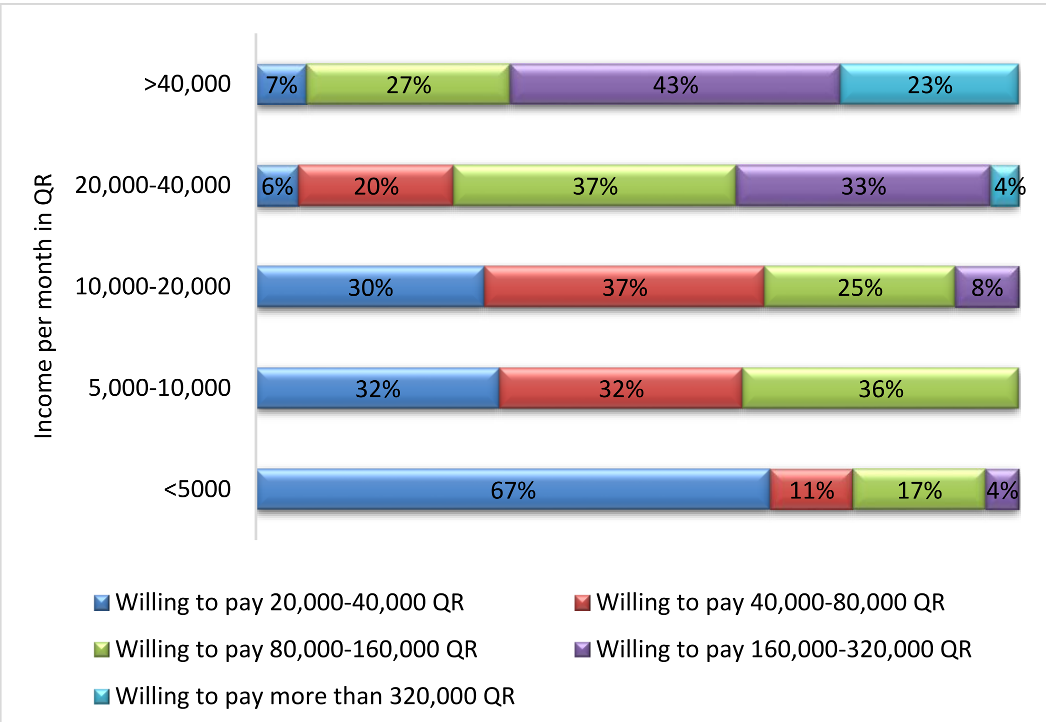

Figure 15. Relationship between the income and purchasing power in Qatar

It is worth to mention that around 51% of the respondents have a simple background about self-driving cars from different social media platforms, internet, and newspaper. Likewise, about 27% of the sample mentioned that it is the first time they heard about autonomous vehicles during their participation. Moreover, only 7% of the participants admit that they have a strong background about autonomous vehicles and know what kind of technology are used in as shown in the following pie chart.

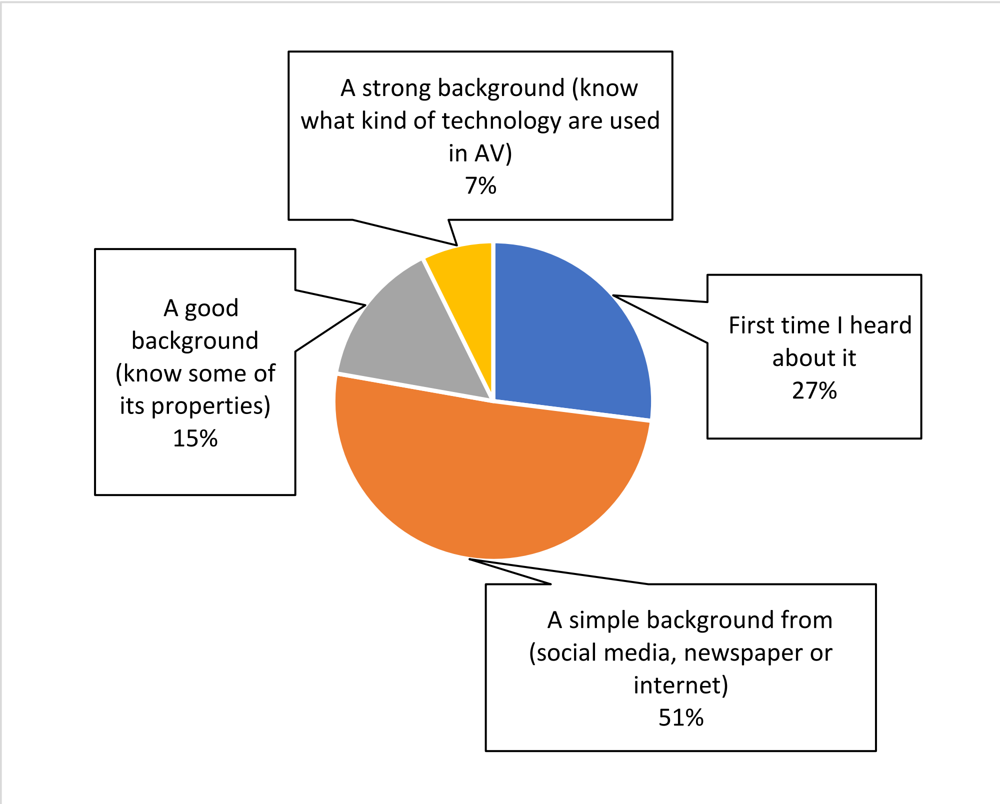

Figure 16. background of the participants about AVs

Regarding the perception of safety, 39% of volunteers have no problem with using driverless cars but they have a minor concern that something could go wrong while using AVs,31% of the participants said that they need to read more about autonomous vehicle and their safety perforce, 16% selected the choice that they have no concern about self-driving cars safety, 9% refuse to use the self-driving cars unless the AVs have the option to shift the control manually, 5% out of all participants refused to use AVs at all.

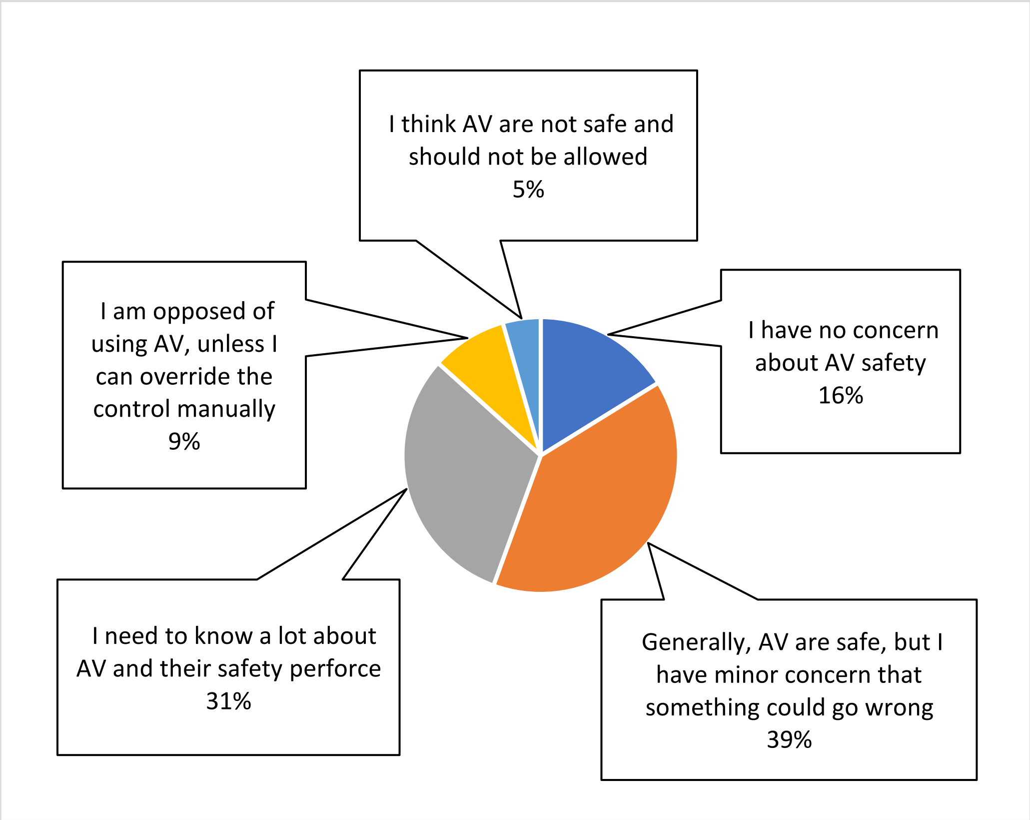

Figure 17. safety issues related to AVs

Additionally, more than 57% of respondents said that they mostly use their cars to travel to their working places, 21% of respondents use their cars for social purposes, 9% of the collected responses specified that they don't have a private car, 8% of respondents use their cars for shopping, and 5% use their cars for other activities as shown in the following figure.

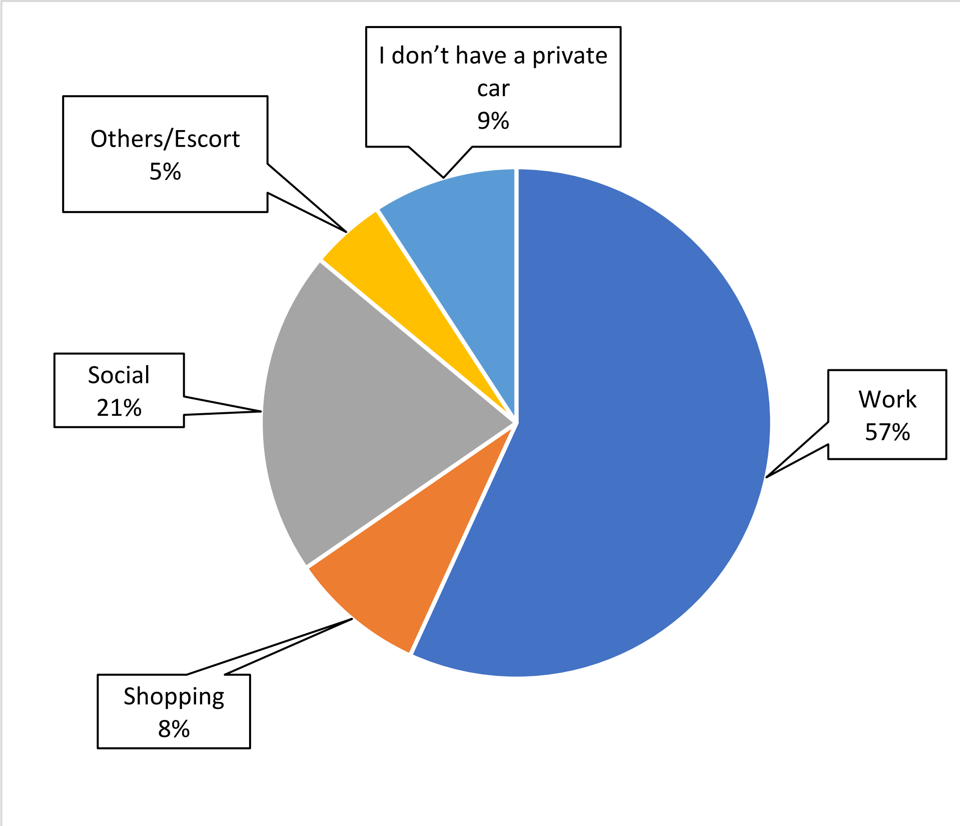

Figure 18. The purpose of using normal car responses

5.2 Data Modeling

Statistical modeling plays an important role in developing and testing theories by using prediction, description, and causal explanation. Moreover, it is also used to explain the behavior of the variables using specific mathematical expressions. Furthermore, it is expected that models with high explanatory power have excellent power of prediction (Shmueli, 2010; Rawlings et al., 2006). In this study, statistics will be used as a leverage to forecast results. Lastly, predictive modelling can magnificently predict, past, future or any other unknown incident (Granville, 2015).

5.2.1 Model Selection:

In this study the plan was in not using the regression analysis because the target was to predict which alternative is more likely to be selected by an individual (alternatives here is a discrete variable) and individual are making a choice. The problem is a perfect example of discrete choice modelling. Within discrete choice modelling, there are various forms of model exist, multinomial logit regression MNL is the most basic one, and therefore, the plan was to start model analysis with estimation of such model. Multinomial logistic regression was used to understand which mode of transport people in Qatar prefer based on attributes and sociodemographic factors. The dependent variable would be the mode of transport selected, with four categories (normal cars, private own autonomous vehicles, shared autonomous vehicles, and public transport). Moreover, the independent variables would be (travel time, travel cost, comfortable scale, purchase cost, subscription cost, and other sociodemographic factors such as age, education levels, and occupation status). However, choosing the proper statistical model is considered as a critical task. The most necessary part in this process is an understanding of both characteristics and type of research dataset. Nevertheless, in this research, willingness of drivers in Qatar to use Autonomous vehicles among other modes of transport is a function of behavioral, sociodemographic and AV related variables (attributes used in the scenarios). Hence, to model the influences of these variables, multinomial logit model seems quite suitable in this situation.

A respondent preference to choose one of the four modes of transport can be articulated by P(m), here m represents the afore-mentioned modes of transport.

$$P_m = \frac{e^{V_m}}{\sum_{m=1}^{M} e^{V_m}} \qquad (1)$$

The equation (1) represent the formulation of multinomial logit model that is developed based on random utility theory. This model can be estimated using maximum likelihood method, were p is the Probability of selection of mode *m* for an individual, M is the Total number of alternatives modes (in this case they are four), e is the Constant (e= 2.71828), and V_m is the deterministic utility of mode m (for each alternative this is given later in this section).

5.2.2 Selection of alternatives in overall observations:

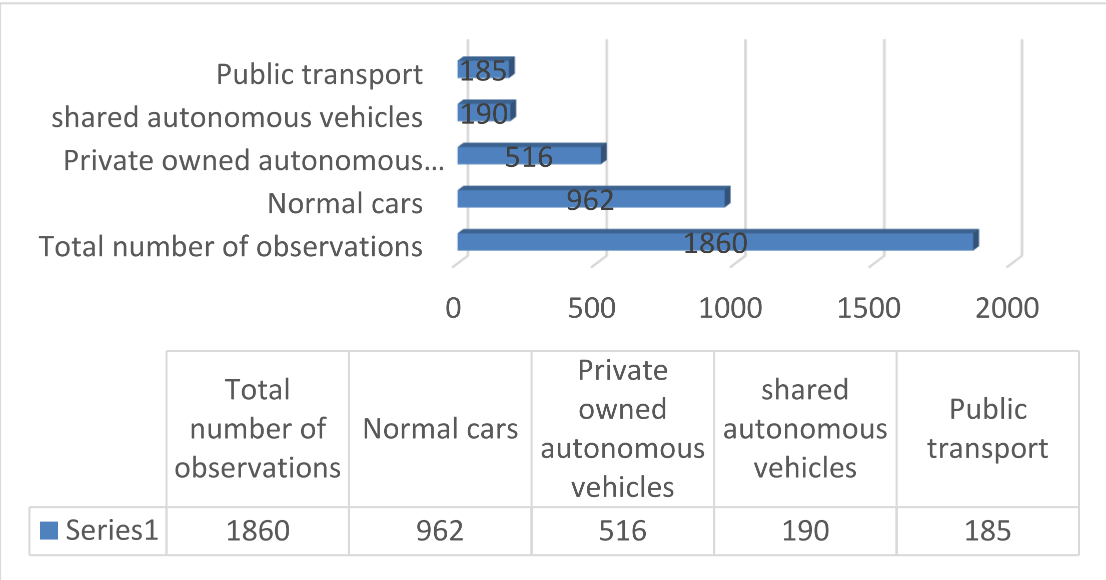

Figure 19. SP- scenario observations

Out of 1860 observed scenarios 962 of the responses recorded the choosing of normal cars, 516 of the responses preferred the use of privately owned autonomous vehicles, 190 scenarios recorded the choosing the shared autonomous vehicles, and the least preferred mode of transport was public transport with only 185 scenarios recorded the choose of such mode of transport.

5.2.3 Model Estimation:

Deterministic Utility for all Alternatives were estimated for general population in Qatar, V_{Car} for conventional normal vehicles, V_{PT} for public transport, V_{AV_Owned} for private own autonomous vehicles, and V_{AV_Shared} for shared autonomous vehicles. However, alternative specific constant ASC for car was determined to be 0, ASC for public transport determined to be -4.19, ASC for PAVs equal -1.88, and ASC for SAVs equal -3.59 as represented in Table.7 below. The values of the coefficients provided for each alternative were confirmed based on reasonableness of the parameter's signs and the statistical significance of the variables incorporated. The utility equations for each mode of transport are presented in the following equations:

$$V_{Car} = ASC_{Car}^{1} + \beta_{TT} \text{ x } TT_{Car} + \beta_{car\_Age} \text{ x } Age + \beta_{car\_CF} \text{ x } CF_{Car} + \beta_{car\_FT\_Emp} \text{ x } FT\_Emp + \beta_{car\_TDPY} \text{ x } TDPY + IA \text{ x } (\beta_{Car\_PC\_IA} \text{ x } (PC_{Car}/INC) + \beta_{Car\_TC\_IA} \text{ x } (TC_{car}/INC))\text{x } + INA \text{ x } (\beta_{Car\_PC\_INA} \text{ x } PC_{Car} + \beta_{Car\_TC\_INA} \text{ x } TC_{Car}) \quad (2)$$

[1] Car is considered as base alternative, therefore ASC_Car is assumed zero.

$$V_{PT} = ASC_{PT} + \beta_{TT} \text{ x } TT_{PT} + \beta_{PT\_Age} \text{ x } Age + \beta_{PT\_CF} \text{ x } CF_{PT} + \beta_{car\_HW} \text{ x } HW + \beta_{PT\_EDU} \text{ x } EDU + \beta_{PT\_NC} \text{ x } NC + \beta_{PT\_DE} \text{ x } DE + IA \text{ x } \beta_{PT\_SC\_IA} \text{ x } (SC_{PT}/INC) \text{ x } 10 + INA \text{ x } \beta_{PT\_SC\_INA} \text{ x } SC_{PT} \quad (3)$$

$$V_{AV\_Owned} = ASC_{AV\_Owned} + \beta_{TT} \text{ x } TT_{AV\_Owned} + \beta_{AV\_Owned\_Age} \text{ x } Age + \beta_{AV\_Owned\_CF} \text{ x } CF_{AV\_Owned} + \beta_{AV\_Owned\_FT\_Emp} \text{ x } FT\_Emp + \beta_{AV\_Owned\_HW} \text{ x } HW + \beta_{AV\_Owned\_DE} \text{ x } DE + IA \text{ x } (\beta_{AV\_Owned\_PC\_IA} \text{ x } (PC_{AV\_Owned}/INC) + \beta_{AV\_Owned\_TC\_IA} \text{ x } (TC_{AV\_Owned}/INC)) + INA \text{ x } (\beta_{AV\_Owned\_PC\_INA} \text{ x } PC_{AV\_Owned} + \beta_{AV\_Owned\_TC\_INA} \text{ x } TC_{AV\_Owned}) \quad (4)$$

$$V_{AV\_Shared} = ASC_{AV\_Shared} + \beta_{TT} \text{ x } TT_{AV\_Shared} + \beta_{AV\_Sahred\_Age} \text{ x } Age + \beta_{AV\_Sahred\_CF} \text{ x } CF_{AV\_Shared} + \beta_{AV\_Shared\_ST} \text{ x } ST + \beta_{AV\_Owned\_UE} \text{ x } UE + \beta_{AV\_Shared\_EDU} \text{ x } EDU + \beta_{AV\_Shared\_NC} \text{ x } NC + \beta_{AV\_Shared\_DE} \text{ x } DE + IA \text{ x } \beta_{AV\_Shared\_SC\_IA} \text{ x } (SC_{AV\_Shared}/INC) \text{ x } 10 + INA \text{ x } \beta_{AV\_Shared\_SC\_INA} \text{ x } SC_{AV\_Shared} \quad (5)$$

Where,

TT_m = Travel time of an alternative mode *m*

ASC_m = Alternative specific constant for an alternative mode *m*

β_{TT} = Estimated parameter of Travel Time (generalised parameter for all alternatives)

Age = Age of an individual (in years, as provided in the data)

β_{m_Age} = Estimated parameter of *Age* for each alternative mode m

CF_m = Comfort Level of the alternative mode m, (can have values 1= good or -1= poor for each alternative)

B_{m_CF} = Estimated parameter of Comfort Level for alternative mode *m*

FT_Emp = Full time Employment Status of an individual (can have values 1 = yes or 0= No)

$B_{m\_FT\_Emp}$ = Estimated parameter of FT_Emp for alternative mode *m*

HW = House wife Status (can have values 1= yes, 0=No)

β_{m_HW}= Estimated parameter of HW status for alternative mode *m*

ST = Student Status (can have values 1= yes, 0=No)

β_{m_ST}= Estimated parameter of ST status for alternative mode *m*

UE = Unemployed Status (can have values 1= yes, 0=No)

β_{m_UE}= Estimated parameter of UE status for alternative mode *m*

EDU = Education status of an individual (can have values *1, 2,and 3* corresponding to *high School or less*, bachelors/diploma and Masters/PhD respectively)

β_{m_EDU}= Estimated parameter of EDU status for alternative mode *m*

NC = Household with No Car Ownership (can have values 1=yes, 0 =No)

β_{m_NC}= Estimated parameter of NC status for alternative mode *m*

DE = Number of years of Driving Experience (as given in data, in years, values are considered zero for individuals having no driving experience)

β_{m_NC}= Estimated parameter of DE for alternative mode *m*

TDPY = *D*istance per year travelled by an individual (can have values 1, 2, 3, 4 and 5 corresponding to <10K, 10K-20K, 20K-30K, 30k-40K and >40K km respectively)

β_{m_TDPY}= Estimated parameter of TDPY for alternative mode *m*

IA = Income Applicable (Individual responded to income question, 1= yes, 0=No)

INA = Income Not applicable (Individual choose not to responded to income question, 1= Yes, 0=No)

$\beta_{m\_SC\_IA}$ = Estimated parameter for Subscription Cost when IA =1, for particular mode m

$\beta_{m\_SC\_INA}$ = Estimated parameter for Subscription Cost when INA =1, for particular mode m

INC = Income Value x 0.0001 (Use a middle value of a particular category that individual have choosen, see attached excel file, code sheet)

SC_m = Subscription Cost of mode m (as given in scenario) x 0.001

$\beta_{m\_PC\_IA}$ = Estimated parameter for Purchase Cost when IA =1, for particular mode m

$\beta_{m\_PC\_INA}$ = Estimated parameter for Purchase Cost when INA =1, for particular mode m

PC_m = Purchase cost of mode m (as given in scenario) x 0.00001

$\beta_{m\_TC\_IA}$ = Estimated parameter for Trip Cost when IA =1, for particular mode m

$\beta_{m\_TC\_INA}$ = Estimated parameter for Trip Cost when INA =1, for particular mode m

TC_m = Trip cost of mode m (as given in scenario) x 0.1

5.2.4 Model Building:

A well thought out, sequential process had been followed to build a comprehensive model. Total of more than fifteen variables was tested for the final model. The variables are related to attributes used in the SP-scenarios, socioeconomical questions, and driving habits questions. These variables will be analyzed under several conditions using maximum likelihood method and Biogeme software. The step by step process is described here below:

a- **Development of dataset:**

It is clarified in the descriptive analysis that most of the participants who did the survey was male (71%) from different nationalities and age groups. The majority of the participants have a high level of education with (52% of the sample have a bachelor's degree). Therefore, the data set would be created in one model. The set will include only responses from people above 18 years old and have a permit residency in Qatar.

b- Development of the model:

In this section, all the variables concerned were used at once for the regression analysis. Before moving forward, it is important to note that the complete dataset based on original values that includes 1860 scenarios. The regression results showed that P-values of the most decided variables did not exceed 10%. This part in model building process, plays a significant role in observing the relationship between different kinds of variables and their influence on the overall significance of the model, by distinguishing the significant and insignificant variables used before finalizing the model. It is important to mention that the confidence interval was decided to be 90%.

5.3 Final model:

In this section, the data set will be finalized by ignoring the insignificant variables with p-values exceed 10%. The following Table.7 shows the last updated dataset which includes the final developed model. The constructed equations (1)-(4) above were estimated in Biogeme software by using maximum likelihood method. The estimation results for the 1860 observations are provided in Table.7. the final log-likelihood of the model is equivalent to -1977 and the rho-square for the model is equal to 0.235 as presented in Table 6.

Furthermore, the outcomes presented in Table 7 provides all the considered variables, p-values, constants used to get the p-values, t-test values, and standard error.

Table 6. Model estimation table: represent the results after generating the maximum liklihood method

Data	Results
Init log likelihood:	-2585.439
Final log likelihood:	-1977.669
Likelihood ratio test for the init. model:	1215.541
Rho-square for the init. model:	0.235
Rho-square-bar for the init. model:	0.223
Number of estimated parameters:	32
Sample size:	1860
Excluded observations:	6

Table 7. Final developed multinomial logit model

Name		Alternative	Value	Std err	t-test	p-value
ASC2	Constants	Public_Transport	-4.19	0.414	-10.1	0
ASC3		AV_Owned	-1.88	0.297	-6.35	0
ASC4		AV_Shared	-3.59	0.419	-8.57	0
b_Travel_time	Travel time	All	-1.55	0.363	-4.26	0
b_Comfortable 1	Comfortable	Normal_Car	0.341	0.0523	6.52	0
b_Comfortable 2		Public_Transport	0.237	0.0818	2.9	0
b_Comfortable 3		AV_Owned	0.347	0.0603	5.75	0
b_Comfortable 4		AV_Shared	0.516	0.09	5.73	0
b_SC_income2	(Subscription cost*0.001/Income *0.0001)	Public_Transport	-0.072	0.0421	-1.72	0.09

b_SC_income4		AV_Shared	-0.02	0.0118	-1.7	0.1
b_SC_income_NA2	(Subscription cost*0.001)*Dummy Income Not Applicable	Public_Transport	-0.378	0.17	-2.22	0.03
b_SC_income_NA4		AV_Shared	-0.077	0.0456	-1.69	0.1
Name		Alternative	Value	Std err	t-test	p-value
b_PC_income1_3	(Purchase cost *0.00001/Income *0.0001)	Normal_Car & AV_Owned	-0.028	0.0163	-1.72	0.09
b_PC_income_NA_1_3	(Purchase cost*0.00001)* Dummy Income Not Applicable	Normal_Car & AV_Owned	-0.162	0.0952	-1.7	0.1
b_Trip_cost_Income1_3	(Trip cost* 0.1/Income* 0.0001)*1000	Normal_Car & AV_Owned	-0.12	0.0238	-5.03	0
b_Trip_cost_Income_NA1_3	(Trip cost*0.1)*Dummy Income Not Applicable	Normal_Car & AV_Owned	-0.123	0.0723	-1.7	0.1
b_Full_time_employee1	Occupation status	Normal_Car	-0.324	0.18	-1.8	0.07
b_Full_time_employee3		AV_Owned	-0.428	0.23	-1.86	0.06
b_Housewife2		Public_Transport	-0.891	0.507	-1.76	0.08
b_Housewife3		AV_Owned	-1.15	0.427	-2.69	0.01
b_Student4		AV_Shared	0.532	0.22	2.42	0.02
b_Unemployed4		AV_Shared	1.06	0.392	2.7	0.01
b_age1	Age	Normal Car	0.0458	0.0093	4.94	0
b_age2		Public_Transport	0.0299	0.0117	3.44	0
b_age3		AV_Owned	0.0458	0.0093	4.94	0
b_age4		AV_Shared	0.0404	0.0115	2.61	0.01
b_education2_4	Education	AV_Shared & Public Transport	0.289	0.0645	4.48	0
b_nr_hh_cars_02_4	Household with no car	AV_Shared & Public Transport	1.4	0.195	7.18	0
b_nr_years_driving2_4	Number of years driving	AV_Shared & Public Transport	-0.051	0.0183	-2.8	0.01
b_nr_years_driving3		AV_Owned	-0.05	0.0157	-3.17	0
b_travel_distance_per_year1	Travel distance per year	Normal_Car	-0.082	0.0401	-2.05	0.04

5.4 Model results:

5.4.1 Preference of public transport (PT):

Transportation services are important to attract tourists from outside country, commuting low income labors from one place to another, and providing safer transport services. Also, public transport plays an effective role in meeting national air quality standards by achieving congestion mitigation and reducing the percentage of greenhouse gaseous emissions. In addition, using public transport as a main mode choice will save a massive amount of energy, which could have been lost due to more fuel consumption, more cars manufacturing, and the needs of constructing more transportation infrastructure.

5.4.1.1 attributes affecting the preference of PT:

The observed attributes which influences the using of public transport in Qatar are:

Firstly, comfortable scale, as clarified in previous table with t-value (2.9) when comfortable scale is good more people would prefer the use of public transport. For instance, the people in Qatar are safety conscious and would prefer the adoption of such mode of transport if it guarantee their comfortable safe ride. Secondly, with t-values= -1.72 for participants with known income and -2.22 for participants with unknown income, subscription cost negatively affects the use of public transport. In which when subscription cost increases less people will prefer to adopt buses or metro in Qatar, especially people with low income and low education level. Third point concerns the travel time. According to collected data received from participants, people in Qatar conscious about the importance of short travel time because they have limited time to spend traveling from home to workplace and vice versa. Hence, they would prefer to use any of the mentioned modes of transport which will deliver them to their destinations as fast as possible. In case of public transport, the travel time has a significant negative effect (-4.26). Increasing the trip time will lead to disuse the public transport in Qatar.

5.4.1.2 Sociodemographic factors affecting the preference of PT:

The obtained results revealed that there is a difference in public transport preference between men and women. the outcomes confirmed that women especially housewife's do not prefer public transport (-1.74). This could mean that female take into consideration privacy and comfort. In other word, they are preferring transport modes which will provide certain services such as unshared mode of transport with others, also the mode of transport should be air conditioned with good temperature and clean seats. On the other hand, men are not critical in selecting the mode of transport as females. They would use public transport if it guarantees reliable, comfortable, safe, and short time ride sharing. Age is an influencing factor that has an association with public transport mode preference. As shown in Figure. 20 Evidence proposed that participants between 25 and 35 years ranked the first place in preferring the adoption of public transport with 32 percentage out of 185 observations recorded in public transport. The second age group was between 36-45 years with 24% of individuals preferred the public transport. The least number of age group who would prefer the use of buses and metro was individuals above 54 years with only 5% preference.

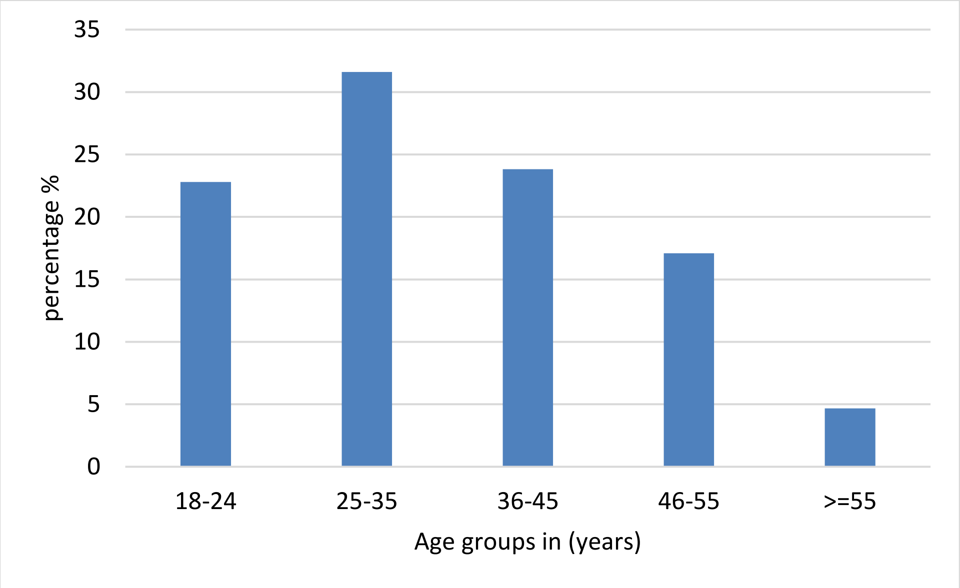

Figure 20. participants prefered PT categorized into age groups

in term of adoption of public transport, people with low income and without an owned private car would prefer the use of public transport more than other modes of transport with high t-vale equivalent to (7.18). After obtaining a significant positive t-value (4.48) in education category it is worth to mention that the higher the education level of the individual the higher the possibility of using such mode of transport.

5.4.2 Preference of shared autonomous vehicles (SAV)

shared autonomous vehicle or in other word driverless taxi raises new opportunities for transportation system. which could mitigate traffic congestion, enhance the safety through application of new technologies such as (V2I) vehicle to infrastructure and (V2V) vehicle to vehicle communication, provide competitive (MOD) mobility on demand services, and could play a significant role in reducing the number of vehicles in future.

5.4.2.1 attributes affecting the preference of SAVs:

According to the recorded results, the attributes which impact the usage of shared autonomous vehicles are similar to the attributes which affect the preference of public transport. First attribute is the comfortable scale. After analyzing the collected data as provided in Table # 7 and clarified in Figure. 21. It is confirmed that the higher the comfortable scale the higher the possibility to shift and use shared autonomous vehicles as an alternative mode of transport as proved with positive coefficient (5.73). This result is due to the fact that SAV will provide the user with information about who will share the vehicle with him/her, SAV will not stop for board and egress the passengers until it reach the desired destination, and SAV will pick the user from his/her position. So, the user will not have to walk or move from station to another as in public transport mode. Secondly, subscription cost, the model gave negative results and confirmed that when subscription cost increases the number of individuals willing to use SAVs decreases, as expected. The third attribute examined was the travel time. It is obvious from table# 7 that there is inversely proportional relationship between the travel time and selection of SAV and other modes of transport. In which the longer the travel time the lower the number of individuals who will use any of four modes of transport including SAVs. It is a reasonable result, because the passenger could make their travel time more efficient. However, SAVs could become a favorable mode of transport for many people if it would guarantee the seating availability, reduce the walking time, and reduce the trip duration.

Figure 21. comparison between number of observations in two comfort scale levels

5.4.2.2 Sociodemographic factors affecting the preference of SAVs:

The results demonstrate that there is no strong relationship between gender and the propensity to use SAVs, except that housewife's in Qatar do not prefer the use of SAVs. Around 12% of the female's responses preferred the use of SAVs as a main mode of transport, and 10% of the overall men's responses selected the SAVs as the preferred transportation method among other modes of transport. Regarding the age factor, the observations illustrated that all age groups from 18 to above 55 years have the same tendency to adopt SAVs in the future. With positive t-value (2.61). it is important to mention that among all ages of individuals, SAVs is preferred more in comparison with PT. For the occupation status, students and unemployed individuals have higher tendency to use SAVs than other same categories. A positive coefficient results for both occupation status was observed. Furthermore, in term of adoption of SAVs, people with higher education level have higher possibility to use such mode of transport than lower educated people.

5.4.3 Preference of Private owned autonomous vehicles (PAVs)

Investigating the preference of PAVs among Qatari residents is one of the important roles in this study. Especially, when level 4 of vehicles which provides automated driving transport services is expected to be released before the end of 2022 and people in Qatar would prefer the use of their owned vehicles more than other shared modes of transport. Introducing PAVs to take the place of conventional regular cars is anticipated to enhance the traffic flow, solving problems related to traffic jams, mitigating the congestions, making use of the capacity of the roads, and eliminating human errors which represents 90% of the car accidents. Therefore, it is vital to explore how the capabilities of PAVs might motivate the drivers in Qatar to shift from regular cars to driverless cars.

5.4.3.1 attributes affecting the preference of PAVs:

The t-test and p-values results obtained for PAVs are plausible. As predicted, enhancing comfortable scale will lead to increase the utility of using PAVs. The evidence for the previous deduction can be obtained from Table.7 in comfortable scale category were t-values for PAVs case is equivalent to (5.75). In case of purchase cost, the PAVs and normal cars have the same negative t-value (-1.74). which mean increasing the purchase cost will lead to the disutility of PAVs and normal cars. Moreover, for participants who mentioned their monthly income salary. It is confirmed that the trip cost has the second most influencing attribute right after the comfortable scale in using PAVs. As clarified in Tabel.7 the trip cost factor for individuals with known income have the most negative t-value (-5.03) among all other attributes, increasing the trip cost for sure will result in the disutility of PAVs. For participants with unknown monthly income, the trip cost has also a negative effect (-1.7).

5.4.3.2 Sociodemographic factors affecting the preference of PAVs:

Difference in preference of PAVs between male and females have not been strongly noted in choice decision. Out of 516 observations selected the PAVs, 121 was female (30% of the overall females' observations) and 395 was male (27% of the overall male observations). In term of occupation status, a negative coefficient resulted (-1.86) for full time employee participants. Which mean people with full time job tend away from using PAVs. Regarding the age, Individuals of all age groups have a high preference for PAVs and normal cars as shown in Tale.7 with positive coefficient equal to (4.94). unexpected negative result observed regarding the driving experience factor. The findings determined that people who have gained more driving experience do not prefer the use of PAVs as the main mode of transport. Another good point to mention, people with higher income tend to have higher willingness to adopt PAVs as represented in the following bar chart.

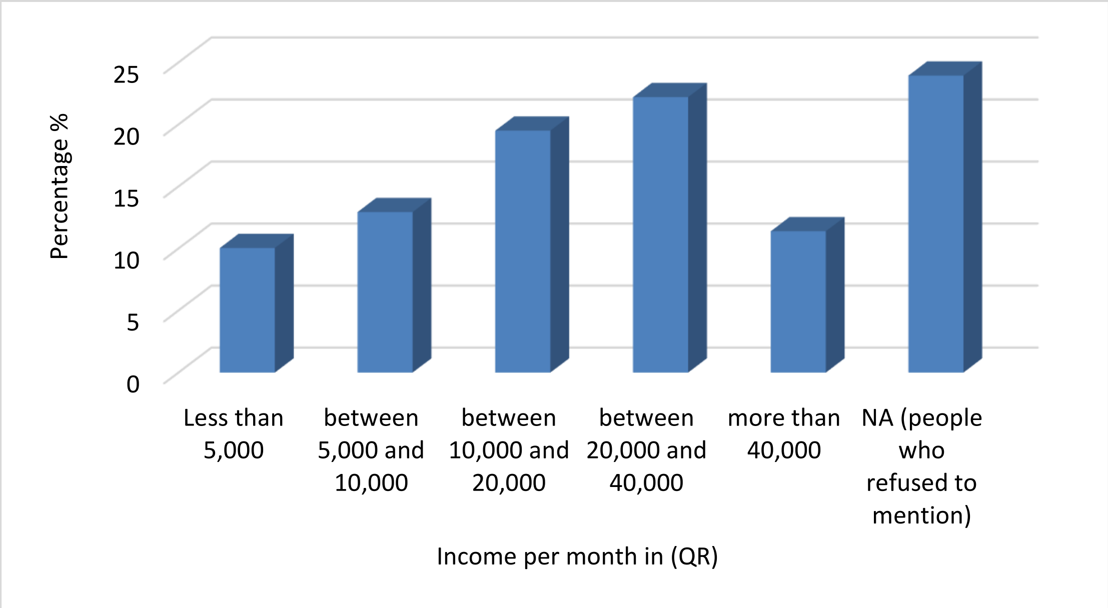

Figure 22. describe the relation between the monthly income salary and willingness to adopt PAVs

CHAPTER 6: CONCLUSION & RECOMMENDATIONS

6.1 CONCLUSION:

Introducing self-driving cars arise a wide range of questions. this research presented the effectiveness of stated preference survey to understand Qatari residents' insight towards different four modes of transport. the online survey consists of five components including collection of socioeconomic questions, driving habits, questions about AVs, Questions related to travel behavior and mode choice, and SP-scenarios. A multinomial logit model is adopted to determine the key preference factors and indicators that can influence the selection of AVs as preferred mode of transport**.** Several key observations were recorded such as:

- There is substantial hesitation toward adoption of AVs in Qatar, with 52% of choice decision remining normal cars.
- Comfortable scale is important factor in Qatar where when the comfortable scale is good it will increase the utility to use such mode of transport.
- among all ages of individuals, SAVs is preferred more in comparison with PT. This is an indication of the captive behavior as individuals reluctant to prefer modes other than their private vehicles. This is in contradiction in relation to findings of other developed world studies, where younger individuals have shown an inclination towards shared modes (such as PT and SAVs).
- Increasing the subscription cost will decrease the utility to use SAV and public transport.
- Education level plays an important role in deciding which mode of transport the respondent will choose. In which the higher the education level of the respondent the higher the probability to use public transport and SAV.

- Housewife do not prefer the use of public transport and PAV.
- Travel time is considered as one of the critical factors. where the Qatari residents prefer to use a mode of transport that will deliver them to their destination in the shortest time.
- Increase the purchase cost of the autonomous vehicles (PAV) will decrease the willingness of people to use it as alternative to the normal car.
- Qatari residents prefer the use of Private own autonomous vehicles (PAV) more than shared autonomous vehicles (SAV).
- Public transport considered the least preferred mode of transport in Qatar especially if the individual owns a private car. In other word, it is clear that people in Qatar give less utility value for SAV and public transport.
- Comfortable scale, travel time, purchase cost, subscription cost, trip cost, and other sociodemographic factors played a significant role in effecting the choice decision between four modes of transport.

Finally, it is important to mention that the sample size of participants in this study was not too large (310 respondents after data screening and treatment stage) and this can be further enhanced in future research works. However, the information and findings in this thesis can provide the transport agencies in Qatar with better understanding about perception and attitude towards AVs in Qatar. In addition, it will highlight the most significant factors that could gain drivers acceptance toward using either PAV or SAV.

6.2 RECOMMENDATION:

Individuals in Qatar are reluctant to prefer modes of transport other than their owned private vehicles. For this reason it is recommended to increase the concern that people have for the environment to encourage them to use public transport and SAVs in the future, enhance their background about AVs by advertising more subjects and videos related to AVs through social medias, television, and newspaper which will show both the positive and negative sides of using such mode of transport. The results of this study proposed that trust in technology is the most important component for people to prefer AVs. Again, to reach this stage people should have strong knowledge about AVs and be exposed for its use. Furthermore, it is highly recommended to continue investing and developing the public transport system in Qatar and encourage Qatari residents to use public transport for longer commutes. Also, educating the public especially the young age group is highly recommended. This could be done by providing a brief presentation in secondary schools and universities explaining the benefits of using AVs, in order to make sure the young generation will gain the required knowledge about AVs before it arises in the market.

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APPENDIX:

Appendix A: Copy of questionnaire questions used in this study

Examining the preference of Autonomous vehicle among Qatari resident's survey

Consent

Thank you for taking the time to complete the survey. This questionnaire aims to investigate the perception of people about autonomous cars (Driverless cars), mainly to understand the public's concerns, opinions, and preferences about this emerging technology. This questionnaire targets individuals that are older than 18 years old and own a driving license.

All given responses will be treated with the utmost confidentiality. The results will be only used for research purposes and no attempt will be made to identify any individual or organization in any publication.

The questionnaire shall take around 20 minutes to complete. Upon the completion of the survey, you will have the chance to win a 100 QAR Coupon. 50 coupons will be randomly distributed to participants who successfully completed the survey. Successful winners will be contacted via email, after closing the surveying to collect their coupons. Please, make sure you enter a valid email address at the end of the online survey.

Your feedback is valuable to us. Please answer the questions truthfully.

Dr. Wael Alhajyaseen Qatar Transportation and Traffic Safety Center Tel: (974) 4403-6679 Email: wyaseen@qu.edu.qa	Qatar Transportation and Traffic Safety Center Qatar University Tel: (974) 4403-4338 Fax: (974) 4403-4302 E-mail: qttsc@qu.edu.qa

Please choose appropriate one or fill out (……….) below.

PART A: Socioeconomic questions:

1- Age?

[ ] Years

2- Gender?
- a- Male
- b- Female

3- Nationality?
- a- Qatari
- b- Non-Qatari/Arab
- c- USA/Canada
- d- Australian
- e- Europe
- f- Asian
- g- others

4- Marital status?
- a- Single
- b- Married
- c- Married with children

5- Type of employment?
- a- full time employee
- b- part time employee
- c- student
- d- housewife
- e- Unemployed
- f- others

6- Highest education level?
- a- High school or less
- b- Diploma degree
- c- Bachelor's degree
- d- Graduate (Masters or PhD)

7- Average income per month?
- a- NA
- b- < 5,000 QR
- c- 5,000-10,000 QR
- d- 10,000-20,000 QR
- e- 20,000-40,000 QR
- f- More than 40,000 QR

8- Number of individuals above 18 years old in your household?
- a- 1
- b- 2
- c- 3

d- 4
e- 5
f- more than 5

9- Total number of cars in your household?

a- 0
b- 1
c- 2
d- 3
e- 4
f- More than 4

PART B: Driving Habit

B1- Number of years of driving experience?

a- No driving licenses
b- Less than one year
c- 1-4 years
d- 5-9 years
e- 10-20 years
f- >20 years

B2- Do you own a car?

a- Yes
b- No

B3- Average travelled distance per year?

a- <10,000 KM
b- 10,000- 20,000 KM
c- 21,000- 30,000 KM
d- 31,000- 40,000 KM
e- >40,000 KM

B4- How much did you pay for your current car or how much you are willing to pay for a new car?

a- 20,000- 40,000 QR
b- 40,000- 80,000 QR
c- 80,000- 160,000QR
d- 160,000- 320,000QR
e- More than 320,000 QR

PART C: Questions about autonomous vehicles (AV)

Brief description:

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. However, autonomous vehicles can be: privately owned (in which you own the car) or shared with other users (you need subscription to a shared autonomous vehicle system, in which you do not own the vehicle but have access to use the autonomous vehicle whenever you need it)

C1- How much did you know about AV?

a- First time I heard about it
b- A simple background from (social media, newspaper or internet)
c- A good background (know some of its properties)
d- A strong background (know what kind of technology are used in AV)

C2- Select one statement representing your perception on the safety of AV.

a- I have no concern about AV safety
b- Generally, AV are safe, but I have minor concern that something could go wrong
c- I need to know a lot about AV and their safety perforce
d- I am opposed of using AV, unless I can override the control manually
e- I think AV are not safe and should not be allowed

C3. How much do you agree or disagree with the following statements?

(C_3-1) Introducing AV will reduce the congestion on the roadways.

a- Strongly agree
b- Agree
c- Neutral
d- Disagree
e- Totally disagree

(C_3-2) Introducing AV will reduce fuel consumption.

a- Strongly agree
b- Agree
c- Neutral
d- Disagree
e- Totally disagree

(C_3-3) Introducing AV will reduce travel time.

a- Strongly agree
b- Agree
c- Neutral
d- Disagree

e- Totally disagree

(C_3-4) Introducing AV will reduce parking cost.

a- Strongly agree
b- Agree
c- Neutral
d- Disagree
e- Totally disagree

(C_3-5) AV can encourage me to travel long distance trips more often.

a- Strongly agree
b- Agree
c- Neutral
d- Disagree
e- Totally disagree

(C_3-6) AV can allow me to visit places which I feel difficult to reach it through regular car.

a- Strongly agree
b- Agree
c- Neutral
d- Disagree
e- Totally disagree

(C_3-7) AV can make my travel more comfortable.

a- Strongly agree
b- Agree
c- Neutral
d- Disagree
e- Totally disagree

(C_3-8) AV can eliminate the human errors causing vehicle accidents.

a- Strongly agree
b- Agree
c- Neutral
d- Disagree
e- Totally disagree

C4. How much do you agree or disagree with the following concerns about AV?

(C_4-1) I have concerns about securing the autonomous driving system from computer hackers.

a- Strongly agree
b- Agree
c- Neutral
d- Disagree
e- Totally disagree

(C_4-2) I have concerns about possibility of accident between regular cars and autonomous vehicles.

a- Strongly agree
b- Agree
c- Neutral

d- Disagree
e- Totally disagree

(C_4-3) I have concerns about increase in maintenance cost in term of (updating computer system of the AVs, changing equipment's costs).

a- Strongly agree
b- Agree
c- Neutral
d- Disagree
e- Totally disagree

(C_4-4) I have concerns about the performance of autonomous vehicles in harsh environmental conditions (such as during raining weather condition)

a- Strongly agree
b- Agree
c- Neutral
d- Disagree
e- Totally disagree

PART D: Questions related to travel behavior and mode choice

D1- For what purpose you travel most by car (work, shopping, social, escort)?

a- Work
b- Shopping
c- Social
d- Others/Escort

D2- In average how many kilometers you travel per work trip (only answer if you use a private car otherwise skip this question)?

a- 5KM or less
b- 6KM-10KM
c- 11KM-20KM
d- 21KM-30KM
e- More than 30KM

D3- In average what is the total travel time per day that you commute from home to work (only answer if you use a private car otherwise skip this question)?

a- Less than 10 min
b- 10-20min
c- 21-30min
d- 31-40min
e- More than 40min

D4- What mode of travel do you use for daily commute?

a- Private car (driver)
b- Private car (passenger)
c- Bus
d- Walk
e- Bicycle
f- Taxi

g- Others

D5- Would you switch to use autonomous vehicle if both regular and autonomous vehicle have the same travel time and travel cost?

a- Yes

b- No

D6- If you don't own a driving license yet, or not able to drive (elderly/person with disability), or currently use other mode choice such as (public transport or taxi) would you switch to use autonomous vehicles?

a- Yes

b- No

D7- How would your number of trips or travel distance change compared to your current travel patterns?

a. No change
b. Slight increase (10-20% more)
c. Moderate increase (20-50% more in distance)
d. Considerable increase (50%-100%)
e. Significant increase (at least 2 times more)

D8- Overall, after considering advantages & disadvantages of using autonomous vehicle, would you like shift to use autonomous vehicle?

a- Yes, I would use autonomous vehicle

b- No, I would not use autonomous vehicle

PART E: SP- Scenarios

Travel modes will be used in SP-Scenarios:

1- Normal passenger vehicles
2- Privately owned Autonomous vehicles
3- Shared Autonomous vehicles
4- Public transit (which includes both Metro and public buses)

Terminologies used:

5- **Normal vehicle:** passenger car
6- **Private autonomous vehicle:** is the privately owned high functional car which can drive itself from a starting point to a predetermined destination.
7- **Shared autonomous vehicle:** it is the high functional car which you need subscription to a share the autonomous vehicle system, in which you do not own the vehicle but have access to use the autonomous vehicle whenever you need it).
8- **Public transit:** means the use of public buses and metro.

Variables used:

6- **Purchase cost:** is the price of the car
7- **Trip cost:** how much is going to cost you to reach your destination, it includes the fuel cost and parking cost in case of the normal car, and fuel cost plus interest and parking cost in case of using other options**.**
8- **Subscription cost per year:** A subscription-based pricing model is a payment structure that allows a customer or organization to purchase or subscribe to a transport services for a 12 months period for a set price. In general, Subscribers typically commit to the services on a monthly or annual basis.
9- **Average trip duration:** average travel time to commute from a place to another within a 20km distance
10- **Comfort scale for each of two options (good, bad):** the evaluation of comfort experienced by both drivers and passengers while using different transport mode choice

Scenarios:
Block#1

1)

Scenario No.	PC	Subscription cost/ year	Trip Cost	Travel Time	Comfort scale	Alternatives
1	30000		23	40	good	Car_Normal
1	30000		24	48	poor	AV_Owned
1		8100	0	52	good	AV_Shared
1		2000		80	poor	Public_transport

2)

Scenario No.	PC	Subscription cost/ year	Trip Cost	Travel Time	Comfort scale	Alternatives
2	30000		23	40	good	Car_Normal
2	30000		24	48	poor	AV_Owned
2		5400	0	64	good	AV_Shared
2			5	40	poor	Public_transport

3)

Scenario No.	PC	Subscription cost/ year	Trip Cost	Travel Time	Comfort scale	Alternatives
3	30000		23	40	good	Car_Normal
3	45000		30	48	poor	AV_Owned
3		5400	0	64	good	AV_Shared
3			3	40	poor	Public_transport

4)

Scenario No.	PC	Subscription cost/ year	Trip Cost	Travel Time	Comfort scale	Alternatives
4	30000		23	40	good	Car_Normal
4	30000		24	48	poor	AV_Owned
4		8100	0	52	good	AV_Shared
4			5	40	poor	Public_transport

5)

Scenario No.	PC	Subscription cost/ year	Trip Cost	Travel Time	Comfort scale	Alternatives
5	30000		18.4	48	good	Car_Normal
5	45000		24	32	poor	AV_Owned
5		2700	30	52	poor	AV_Shared
5		2000		80	good	Public_transport

6)

Scenario No.	PC	Subscription cost/ year	Trip Cost	Travel Time	Comfort scale	Alternatives
6	30000		23	40	good	Car_Normal
6	45000		24	32	good	AV_Owned
6		5400	30	40	poor	AV_Shared
6		2000		80	poor	Public_transport