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An adaptive urban planning framework to support autonomous car technologies

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A thesis submitted in partial fulfilment of the requirements of Nottingham Trent University for the degree of Doctor of Philosophy

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Copyright statement

Declaration

The thesis was submitted according to the rules and regulations of Nottingham Trent University (NTU) for the submission of a research degree thesis. I hereby declare that I am the sole author of this thesis. To the best of my knowledge this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material which has been accepted as part of the requirements of any other academic degree or non-degree programme, in English or in any other language.

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Date:

Dedication

This dissertation is dedicated to the most precious two people in my life, my parents: Ahmed Bezai and Cherifa Ouchen, who have been very unconditionally supportive since day 1. To my sweet and lovely brothers and sisters; Hamid, Bida, Noura, Khaled, Younes, Fatiha, Mohamed, Samira and Amel. To my grandmother Khokha and to the spirit of my grandfather Belkacem.

List of Publications

- **Future cities and autonomous vehicles: analysis of the barriers to full adoption.**
  N.E. Bezai, B. Medjdoub, A. Al-Habaibeh, M.L. Chalal, F. Fadli, Future cities and autonomous vehicles: analysis of the barriers to full adoption, Energy Built Environ. (2020). https://doi.org/https://doi.org/10.1016/j.enbenv.2020.05.002.

- **Autonomous vehicles and smart cities-future directions of ownership vs shared mobility.**
  Bezai, N., Medjdoub, B., Fadli, F., Chalal, M. L., & Al-habaibeh, A. (2020). Autonomous vehicles and smart cities : future directions of ownership vs shared mobility . Logistic regression to predict future use of AVs based on current transportation mode used . In M. Hanzl, J. Reilly, & M. Agrawal (Eds.), 56th ISOCARP World Planning Congress, Virtual Congress. ISOCARP.

- **From discovering to delivering: A critical reflection on eco-feedback, application design, and participatory research in the United Kingdom.**
  M.L. Chalal, B. Medjdoub, R. Bull, R. Shrahily, N. Bezai, M. Cumberbatch, From discovering to delivering: A critical reflection on eco-feedback, application design, and participatory research in the United Kingdom, Energy Res. Soc. Sci. 68 (2020) 101535. https://doi.org/https://doi.org/10.1016/j.erss.2020.101535.

- **Big Data to support sustainable urban energy planning: The EvoEnergy project**
  Journal: Frontiers of Engineering Management.
  Chalal, M.L., Medjdoub, B., Bezai, N. et al. Big Data to support sustainable urban energy planning: The EvoEnergy project. Front. Eng. Manag. 7, 287–300 (2020). https://doi.org/10.1007/s42524-019-0081-9

Abstract

In the last few decades, there has been increased discussion around smart mobility and the development of autonomous vehicles (AVs). The upcoming technology of self-driving vehicles has the potential to improve the quality of urban living and enhance sustainability, but our cities are not yet ready to adopt AVs. The physical infrastructure and legislative frameworks required are not yet in place, and public attitudes towards AVs are unclear. Although a great deal of current discussion revolves around the technical aspects of self-driving vehicles and technological maturity, there is a lack of research examining the full range of barriers to AV adoption and the potential impacts on urban planning. In order to begin to fill this gap, this study explores the barriers to full AV adoption in detail and develops an adaptive urban framework to assist urban planners, citizens, politicians, and stakeholders in their planning decision-making around AVs.

To achieve this aim, the study adopts a mixed-methods research methodology following the multilevel model triangulation research design, with four distinct implementation phases. In Phase One, document analysis and content analysis is carried out to identify and analyse the barriers to the adoption of AVs in today's cities and to analyse AV vehicle specifications and assess their potential impact on the urban transportation infrastructure. The analysis identifies key barriers in the following areas: 1) Safety; 2) User acceptance; 3) Regulations and ethics; 4) Accurate positioning & mapping; 5) Computer software & hardware; and 6) Communication Systems (Networks). The outcomes of this phase contribute to the development of a framework of barriers to the full adoption of AVs combined with the AV system architecture, tracing their interrelations, and an initial list of recommendations. In Phase Two, a semi-structured survey targeting experts in a range of disciplines associated with AVs is used to validate the framework developed in Phase One and to determine the possible impacts on city planning and transportation infrastructure of a hypothetical journey through the city of Nottingham made by a fully autonomous vehicle (Level 4). This phase

reveals that the majority of experts believe that both existing design principles and design guidance will be affected, with street elements such as roundabouts/intersections, zebra crossings, charging points, on-street parking, road signs, and drop points most severely affected. For instance, 61% of experts agree that AVs' hubs should be in each neighborhood. 19% of experts argue that manual driving should be banned. In Phase Three, a structured survey targeting members of the public in Nottingham is used to analyse current public attitudes and behaviours in respect of AVs and to begin to identify factors which might drive AV adoption in future. 57% of people are expected to share AVs and 64% are expected to own them in the city. In terms of data privacy, 46% of people disagree with sharing their data.

The final phase of the research involves combining the outcomes of the previous phases to create the final adaptive urban planning framework to support future planning decision-making around AVs. A detailed list of recommendations to address the technical, social and legislative barriers identified is also proposed. The study concludes by suggesting avenues for subsequent research to build on these outcomes and further support the adoption of AVs as part of moves to promote smart mobility and enhance the quality of life in our cities.

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First and foremost, I would like to thank God almighty for giving me health and blessing to achieve this doctoral thesis and make my dream come true.

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List of abbreviation

AD	Automated Driving
AEV	Autonomous Electrical vehicle
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
ARMA	Autoregressive and Moving Average
AV	Autonomous Vehicle
CAV	Connected Autonomous Vehicle
CV	Conventional Vehicle
DCNN	Deep Convolutional Neural Network
DF	Data Fusion
DR	Dead Reckoning
FIR	Fourth Industrial Revolution
GNSS	Global Navigation Satellite System
ICT	Information and Communications Technology
IDS	Intrusion Detection System
IMU	Inertial Measurement Unit
IoT	Internet of Things
IoV	Internet of Vehicles
ITS	Intelligent Transport system

LiDAR	Light Detection and Ranging
MFS	Manual For Street
MPV	Multi-Purpose Vehicle
NHTSA	National Highway Traffic Safety Administration
OBU	On-Board Unit
PCL	Point Cloud Library
RGB	Red Green Blue
RII	Relative Importance Index
RSU	Road-Side Unit
SAV	Shared Autonomous Vehicle
SME	Small And Medium-Sized Enterprises
SUMO	Simulation Of Urban Mobility
SUV	Sports Utility Vehicle
UIS	Urban Infrastructure System
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrians
V2V	Vehicle-to-Vehicle
VANET	Vehicular Ad-hoc Networks
VoT	Value Of Time

Definitions

Automated driving: *"refers to both Advanced Driver Assistance Systems (ADAS) and Automated Driving Systems (ADS). ADAS features on a vehicle support human drivers while an ADS may ultimately be able to operate a vehicle without a human driver"* (ADS Team, 2019)

Autonomous vehicles (AVs): *"is a vehcile that is capable of sensing its environment and navigating without human input"*(Navarro et al., 2016).

"The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle" (Schneble & Shaw, 2021).

Connected autonomous vehicles (CAVs): *"Connected and autonomous vehicles (or CAVs) combine connectivity and automated technologies to assist or replace humans in the task of driving. This can be through a combination of advanced sensor technology; on-board and remote processing capabilities; GPS and telecommunications systems"*(Brake, 2017).

"Connected vehicle technologies provide the opportunity to create an interconnected network of moving vehicular units and stationary infrastructure units, in which individual vehicles can communicate with other vehicles (i.e., V2V communication) and other agents (e.g., a centralized traffic management center through V2I communication) in a collaborative and meaningful manner" (Mahmassani, 2016).

Mobility-on-demand:

"Mobility on Demand (MoD) refers to the ability of individuals to utilize varying transportation modes to make their journeys more efficient or complete. Technology is the bedrock of this approach, often because it allows people to be better informed of the mode options and therefore more productive or efficient"(Spears, 2019).

Shared AV:

"The concept of SAVs combines elements of conventional carsharing and taxi services with AVs. SAVs could provide inexpensive and convenient mobility-on demand services, which have been described as driverless taxis" (Krueger et al., 2016).

Crash avoidance technologies: "*A collision avoidance system, also known as a driver assistance system, is a safety system designed to prevent a collision or decrease its severity in the few seconds before it occurs"* (Samsara, 2021).

Chapter 1: Introduction

Contents

Chapter 1: Introduction

1.1. Background

The cities in which future generations will live are being made, shaped and delivered today; thus, cities must fulfil the needs of today while preparing for the challenges of tomorrow. Climate change, population growth, transportation issues, international security, and globalisation pose the main challenges for future urban development (Kharrazi et al., 2016), and planning and decision-making must take proper account of these, through a process known as ‘future-proofing’ (Hodkinson, 2015). The revolution in social media, mobile phone networking, and the internet of things (IoT) offers excellent opportunities to create healthy, transparent and sustainable cities (Consel & Kabac, 2014; Hachem et al., 2015; Pathak et al., 2015), and the development of smart cities aims to produce sustainable models for urban living and enhance the quality of life in cities (Lom et al., 2016). An overall model of the smart city and the technologies associated with it is provided in Figure 1-1. Figure 1-1, illustrates the smart city’s objectives where the advance of technology is used to address different challenges that are facing cities. The combination of different technologies (Digital world) with the physical world (Cars) leads to the creation of different applications such as Automated driving, and connected autonomous vehicles.

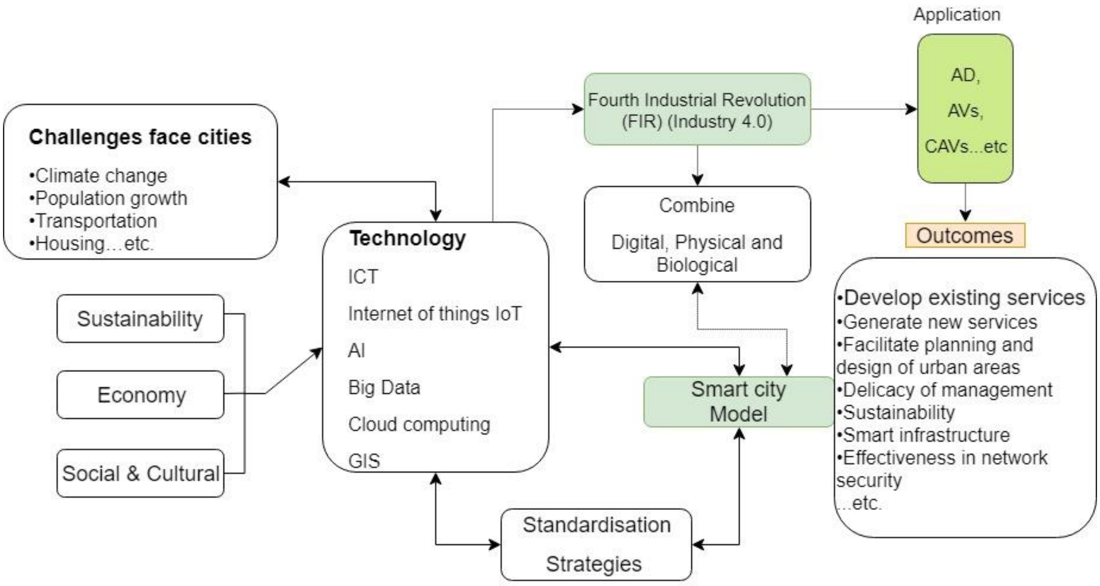


Figure 1-1. Smart city model and its applications.

According to Barcelo, (2019), the development of smart cities involves an intricate web of components, including the development of smart mobility, smart technology, and smart infrastructure (See Figure 1-2). The figure illustrates a smart city and its components (smart technology, smart energy, smart infrastructure and smart mobility) Where smart mobility and smart infrastructure form the urban form.

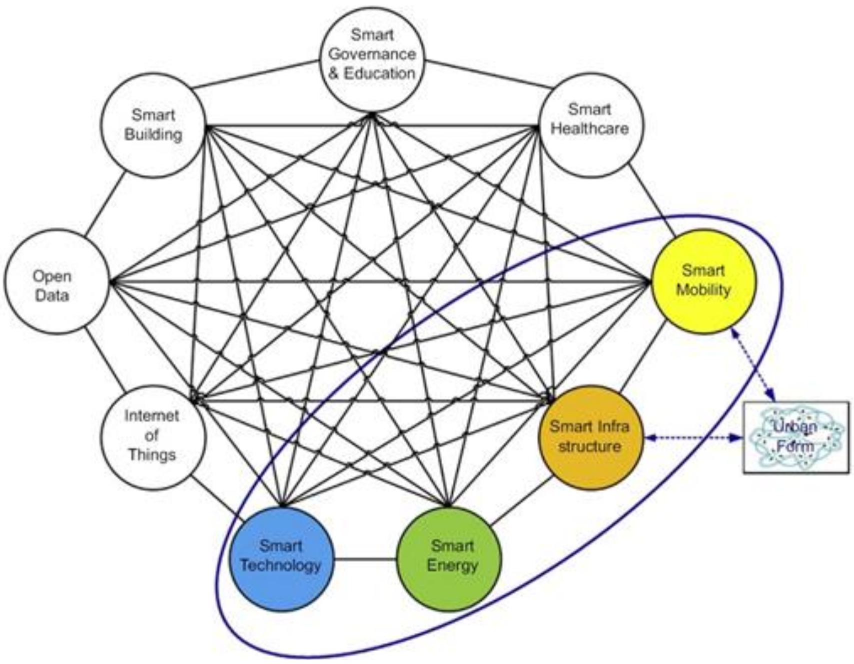


Figure 1-2. Smart City and its components and their relationships (Barcelo, 2019).

Barcelo, (2019) believes that sustainable mobility is established on three concepts: social sustainability, environmental sustainability, and addressing climate change, and that the growth in Information and Communications Technology (ICT) applications will give rise to new concepts in mobility that will radically change transportation infrastructure. A key element of the development of smart mobility is the adoption of autonomous vehicles (AVs), smart, self-driving vehicles which navigate by means of sophisticated sensors and processing technologies. These have the potential to revolutionise transportation, but significant barriers to their widespread adoption exists, notably in urban centres such as today's cities.

This study explores the barriers to the implementation of fully autonomous vehicles in the city of Nottingham in the UK. The research context and the problems the study aims to address are described in the next section.

1.2. Research Context and Problems

Increasing congestion on our roads imposes an obligation upon authorities to expand existing infrastructure to meet rising demand. This is required to save lives. Research indicates that 90% of road accidents are due to human causes (Crovitz, 2014; Richards & Stedmon, 2016), and, according to the European Commission fact sheet on road safety for 2016, 46% of deaths within the EU that year were caused by cars (European Commission, 2017). Despite the advantages that characterise our current transportation systems, several challenges need to be addressed; these include: traffic congestion, pollution, high costs, high rates of accidents and death, and the almost total reliance on non-renewable energy sources (Litman, 2003). However, these challenges are largely being addressed in isolation, rather than in an integrated way, and this is leading to unsustainable solutions. This study explores the adoption of AVs as a 'smart' way to address many of these issues, identifying the barriers to AV adoption and examining them from three main perspectives (technology, urban planning, and legislation/regulations) in order to propose integrated solutions to address them. These perspectives are outlined in relation to AVs in the sections below.

1.2.1. Technology

Shifting from human driving to autonomous driving will be a challenging technological shift similar in scale to the move from horse power to combustion engines (Grush et al., 2016). Several automated systems have already been introduced to assist drivers in decision-making, including cruise control, self-parking, and self-braking, and the level of support provided varies from systems that offer advice to drivers to those that can act autonomously, such as emergency self-braking. In this respect, the driver's role is becoming more like that of a supervisor than a hands-on driver (Richards & Stedmon, 2016). However, despite promises by manufacturers such as BMW, Ford and UBER to provide a fully autonomous car by 2021 (Hörl et al., 2016), they have yet to launch AVs which can perform well in all situations, including different weather conditions, and in urban and suburban environments. Significant concerns also remain about safety and privacy considerations, notably privacy concerns regarding the 'big data' generated by these vehicles (Gallello, 2013). What then are the main technological barriers to AV implementation and how can they be addressed?

1.2.1.1. Levels of automation

As mentioned above, a certain level of automation has already been introduced into conventional cars. As efforts to accelerate automation increase, efforts have been made categorise the different types and levels of automation to enable designers to determine evaluative criteria about what should or should not be automated (all features or only specific features?). Parasuraman et al., (2000) suggested ten levels of automation: the greater the involvement of machines, the higher the level, with Level 1 being no machine assistance and Level 10 being full automation (no human assistance). These levels are presented in Figure 1-3. Official organisations are now starting to adopt their own categorisations, notably The

National Highway Traffic Safety Administration (NHTSA), a U.S. federal government agency. They have developed a scale involving five levels of automation, with Level 0 being no automation and Level 4 being full self-driving automation (See Table 1-1).

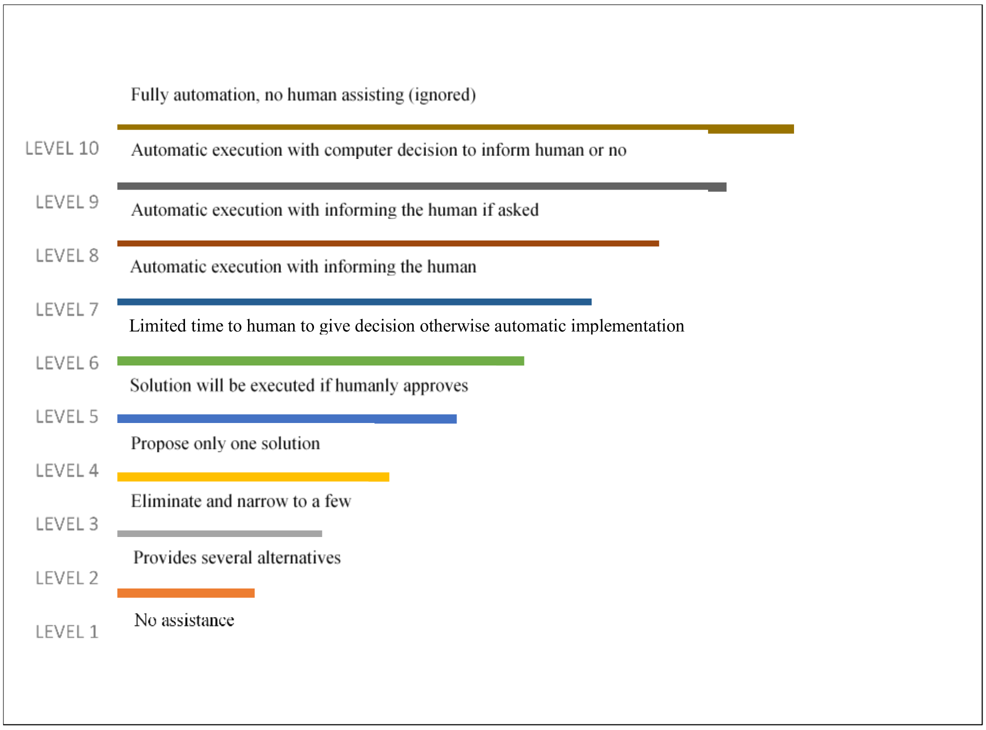


Figure 1-3. 10-point scale of Vehicle Automation *created by Parasuraman, Sheridan and Wickens, (2000)* (Parasuraman et al., 2000).

Table 1-1. NHTSA's levels of Vehicle Automation (NHTSA, 2013).

Level 0	No-Automation
Level 1	Function-specific Automation
Level 2	Combined Function Automation
Level 3	Limited Self-Driving Automation
Level 4	Full Self-Driving Automation

1.2.2. Urban Planning

It is believed that autonomous cars will bring a number of significant benefits, including increased safety, reduced traffic congestions, pollution, fuel consumption and greater mobility for disabled and older people (Banchiri, 2016; NHTSA, 2013). However, driverless cars will require rethinking the design of our roads, streets, and neighbourhoods and this will affect future planning processes (Urry, 2013). Urry, (2013) has predicted four scenarios of future mobility, particularly transportation modes using cars. The fourth scenario involves combining the digital revolution with transportation economies to enable digital software to work intelligently to get tasks done in the most effective way. But what will this mean for the design principles and elements of contemporary urban street design? What will our planners need to consider to prepare our transport infrastructure for the arrival of AVs?

1.2.3. Regulations

The legislation which currently governs the use of motor vehicles assumes that a driver will be in control of the vehicle. For example, Article 8 of the 1968 Vienna convention on road traffic asserts that "Every driver shall at all times be able to control his vehicle" (United Nations Conference on Road and Motor Transport, 1968). This naturally presents an obstacle to the introduction and testing of self-driving vehicles and their entry into the market (Miles & Graff, 2014). However, amendments stating that automated systems "can be overridden or switched off by the driver" (Economic and Social Council, 2014) have allowed automation at Levels 1 and 2 (See Table 1-1) to be achieved and regulations to be established. Notwithstanding, additional legal debate and amendments will be needed to allow fully autonomous cars to operate in the future and to enable testing to be carried out in current cities. In 2013, the UK government pledged to create a legislative and regulatory framework to authorise driverless car tests on public roads (HM Treasury, 2013), and plans were announced in the 2013 Autumn Statement. Furthermore, in July 2014, a £10 million prize competition was launched inviting UK cities to develop testing areas for autonomous cars (Department for Transport, 2014). But what changes need to be made at the government level, both to enable testing in cities and to allow fully autonomous vehicles onto our roads?

This study set out to explore the technical, planning-related and legislative barriers to the adoption of AVs and identify possible solutions. Much previous research into AVs is fragmented and largely focused on the technical challenges; however, this study views these barriers as inter-related, rather than studying them in isolation, in order to develop a holistic framework to support urban planning in relation to AVs. The aim and objectives established for this study and the research questions developed are described in the following sections.

1.3. Research Aim and Objectives

The aim of this research is to explore the barriers to the adoption of autonomous cars and develop an adaptive urban framework to assist urban planners, citizens, politicians, and stakeholders in their planning decision-making around AVs. Various objectives have been set in order to achieve the overall aim, as follows:

1. To identify and analyse the barriers to AV adoption in today’s cities.
2. To analyse AV vehicle specifications and their impact on current urban transportation infrastructure.
3. To determine the possible impacts on city planning and the design of future urban transportation infrastructure.
4. To measure and analyse current public attitudes and behaviour in respect of AVs.
5. To develop an urban planning framework to help transportation infrastructure adapt to AVs and propose a set of recommendations.

1.4. Research Questions

The following research questions have been established to guide this research:

1. What are the barriers and obstacles preventing the adoption of AVs in today’s cities?
2. What are the technologies and infrastructures needed to accommodate AVs? Car specifications?
3. Which street design elements and design guidance are most likely to be affected by the integration of AVs into the city’s transport infrastructure?
4. How do potential users’ regard AVs now and how can they be encouraged to adopt AVs in the future?
5. What steps should be taken to help the city’s urban structure adapt to AVs?

1.5. Contribution to knowledge

This study looks at the potential implications of AV adoption from technical, social and legislative perspectives in order to develop an adaptive urban planning framework to assist planners, citizens, politicians, and stakeholders in their planning decision-making. Unlike previous research works, which have tended to focus on technical matters and discuss issues in isolation, this study adopts a mixed methods approach to examine all the barriers together and propose holistic solutions. Thus, the originality of this research contribution lies in the quality of the framework as well as the methodology that has been developed.

More precisely, the contribution is as follows:

- identifying the barriers to AV adoption at the technical, social, and legislative level and map their impacts and connections

- building up a framework for the integration of full AVs into the existing urban infrastructure which considers technical, social and legislative aspects and AVs' impact on urban street design.
- establishing a methodology for the creation of the holistic framework, employing mixed-methods research, in which the outcomes of each phase of the research inform the design and contents of the final framework.
- studying the mindset and attitude of a sample of potential AV users in an urban setting (the city of Nottingham) in order to establish to what extent they accept AVs technologies and usage, what social barriers exist, and what strategies might be adopted to promote AV use.

The next section explains the structure adopted for this thesis and the contents of each chapter.

1.6. Thesis Structure

This research work is presented in six main chapters, as illustrated in Figure 1-4.

Chapter 1: Introduction

This chapter introduces the study by identifying autonomous vehicles as a key element in the drive to develop smart cities, and as a potential means to solve transportation issues and contribute to creating more efficient and sustainable urban systems. It describes the research context and identifies the research problem, then sets out the aim and objectives of the study and research questions. The chapter concludes by outlining the anticipated contribution to knowledge and presenting the thesis structure.

Chapter 2: Autonomous vehicle specifications and barriers to full adoption

This chapter presents an overview of the AV system architecture and provides a comprehensive systematic review of the barriers to full AV adoption in order to understand the factors involved and identify possible solutions. It identifies the key barriers, explores their associated factors, and considers potential solutions. These barriers are then combined with the system architecture to identify their impacts on individual phases and the system as a whole. A conceptual framework is developed which forms the basis for the final urban planning framework and recommendations for further actions are proposed based on the findings of the literature review. The outcomes of this phase of the research informed the development of the survey questionnaires reported in Chapters 4 and 5.

Chapter 3: Research Methodology

This chapter presents the research methodologies adopted to address the objectives set for this study. To achieve the aim of the study, a mixed-methods research methodology was embraced. The chapter begins by discussing the philosophical positions and the research paradigms adopted before going on to describe the research approaches, highlighting the deductive and inductive approaches and how mixed approaches were utilised. Furthermore, the time horizons and the research methodology rationale and research methods are also discussed. The research design and the four phases of the practical implementation are presented, and the chapter concludes by discussing the credibility of the research, looking at the reliability and validity of the study as well as the ethical considerations involved.

Chapter 4: AVs' Urban Impact Analysis and Conceptual Framework Validation: Survey 1 Results And Discussion

This chapter analyses the results of the survey designed for experts in a range of disciplines associated with AVs with the aim of validating the framework developed in Chapter 2, ranking the barriers identified in the literature review in order of importance, and investigating the expected impacts of AVs on urban planning, particularly design principles, design issues, and design guidelines. A survey questionnaire was used for the data collection, and NVivo and SPSS were used to analyse the data. A number of hypotheses were formulated and tested in order to check the validity of the data, The outcomes of this stage contributed to the design of the survey for potential AV users reported in Chapter 5.

Chapter 5: Autonomous Vehicles And User Acceptance Behaviour

This chapter analyses the results of the survey questionnaire which targeted members of the public in Nottingham in order to examine their current attitudes towards AVs and their likely acceptance behaviour in future. The survey was organised around the factors associated with user acceptance and behaviour identified in the literature review. The collected data was analysed using various statistical tests, such as binary logistic regression, performed using SPSS. Cronbach's Alpha was used to check the reliability of the data. A number of hypotheses were formulated and tested to see if aspects of current user behaviour are reliable indicators of future behaviour in regard to AV acceptance and usage. Possible strategies to promote AV adoption among members of the public were also identified.

Chapter 6: Development of the Final Framework, Recommendations and Conclusions

This chapter concludes the study. It begins by explaining how the final framework was developed, then presents the framework itself and proposes a series of recommendations for urban planning to support AV adoption. It provides answers to each of the research questions and explains the contribution to knowledge the study makes. The chapter concludes by setting out the limitations of the current study, noting the impact of the COVID-19 pandemic on the practical implementation, and suggests avenues for further research.

A visual representation of the thesis structure is provided below:

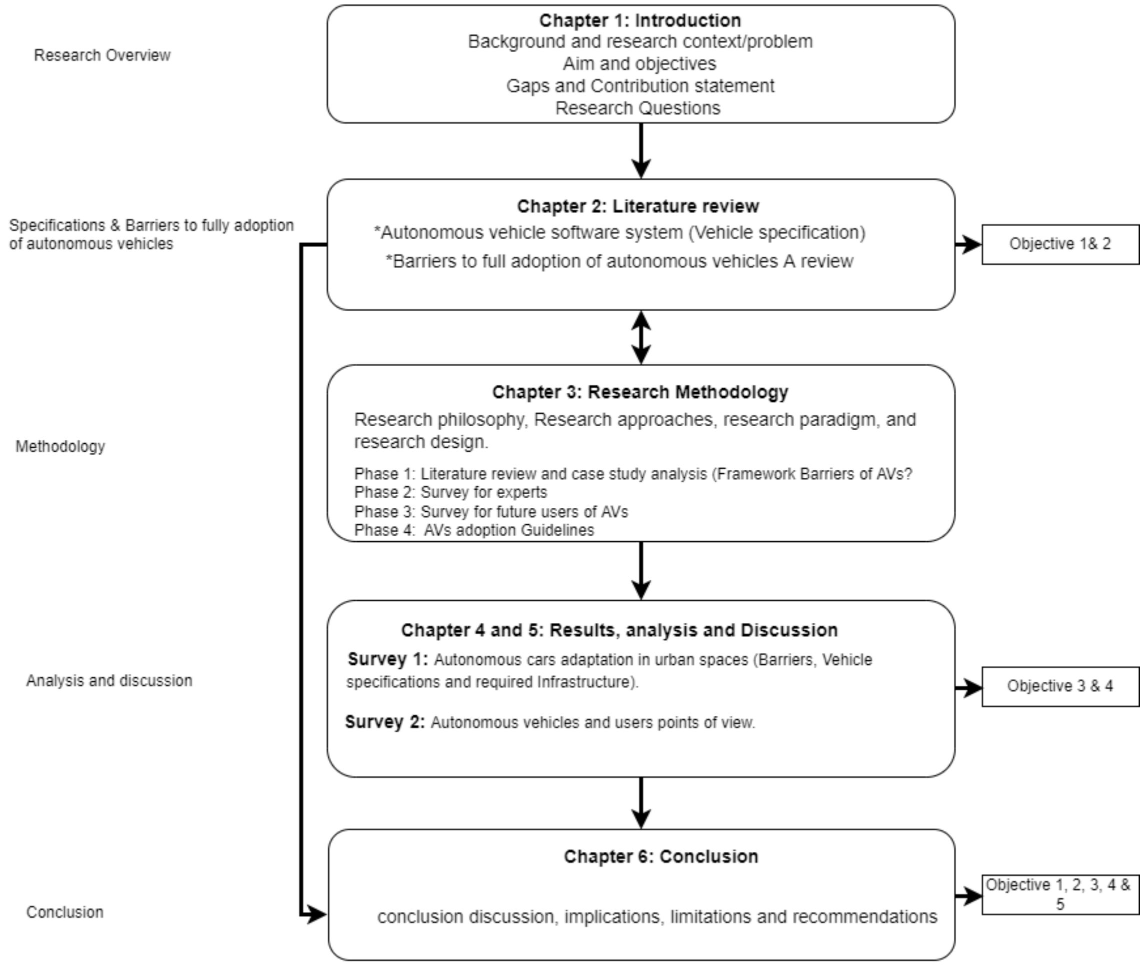


Figure 1-4. Thesis structure and chapters.

Chapter 2: Autonomous vehicle specifications and barriers to full adoption

Content

Chapter 2: Autonomous vehicle specifications and barriers to full adoption

2.1. Introduction

The convergence of the Internet of Things (IoT), big data, cloud computing and artificial intelligence (AI) has been described as the Fourth Industrial Revolution (FIR), and is characterised by combining digital, physical and biological worlds (Schwab, 2017). It is also known as "Industry 4.0" (Xu et al., 2018). Automated Driving (AD), autonomous vehicles (AVs) and Connected Autonomous Vehicles (CAVs) are becoming a significant aspect of the FIR, and scholars have already started to discuss the potential benefits and changes they could bring (Cheong & Lee, 2018; Pieroni et al., 2018). Most of the recent research has highlighted safety as the most prominent benefit, based on the reduction in crashes achieved by "highly effective crash avoidance technologies" (NHTSA, 2013), and the use of components which are sufficiently robust to meet aviation standards (Litman, 2017a). Further benefits which have been identified include innovative freight delivery and independent mobility (Alessandrini et al., 2015), insurance cost reduction (Agarwal et al., 2019; Wadud, 2017), enhanced efficiency of road transport and certain service categories (Alfonso et al., 2018), better control of traffic flow (Stern et al., 2018), including maximising intersection capacity and minimising bottlenecks (Sun et al., 2017), comfort and entertainment services (Atzori et al., 2018; Panagiotopoulos & Dimitrakopoulos, 2018), reduced congestions and increased accessibility (Joiner, 2018; The House of Lords Science and Technology Committee, 2017), energy efficiency (Vahidi & Sciarretta, 2018), Fuel consumption reduction through platooning and 'Right-sizing" of vehicles (Vahidi & Sciarretta, 2018; Wadud et al., 2016; W. Zhao et al., 2018), make travelling by car more attractive (Gruel & Stanford, 2016), offer mobility to people unable to drive (Fagnant & Kockelman, 2015), tourism extension (S. A. Cohen & Hopkins, 2019), economic (Bichiou

& Rakha, 2018), expand new markets and more software and hardware companies to be developed (Bamonte, 2013), social benefits (Bechtsis et al., 2018). Indeed, (Hyatt, 2017) believes that the advent of AVs will be the most substantial change and transition in societies since the creation of the internet.

In order to achieve the benefits associated with AVs, we must understand their advantages and disadvantages and start planning and deploying policies to control their impacts (Riggs et al., 2019). While AVs promise many benefits, there are also potential risks. For example, research has suggested that using both modes of driving (manual and automated) can lead to miscommunication (Straub & Schaefer, 2018), and AVs also face cybernetic threats. The digitisation of the transport system makes it more vulnerable to hacking (Alfonso et al., 2018; Atzori et al., 2018; Kaur & Rampersad, 2018), and AVs have been linked to malicious cyberattacks through a non-trusted network (Kim, 2018). Studies have also indicated that AVs could be exposed to system failure (Agarwal et al., 2019; Alessandrini et al., 2015; S. Kim, 2018).

In order to understand and evaluate the changes that AVs can bring to our cities, it is imperative to firstly comprehend how an AV works, to understand the vehicle specifications, or what is known as the *"autonomous vehicle system architecture".* Secondly, the various barriers that impede the adoption of these technologies must be identified, both to determine the obstacles themselves and to identify the infrastructures required to ensure the smooth performance and safety of AVs. As a result, the following sections discuss the vehicle specifications and requirements of an AV in detail and then explore the potential barriers to full AV adoption identified in the literature. Potential solutions to address these obstacles are also discussed, notably the need for addition ICT infrastructure and legislation.

2.2. Autonomous Vehicle System Architecture (Vehicle specifications)

In order for an AV to operate fully, several phases are required: input, processing, output, and a new communication data phase. The AV framework system can be further divided into Six areas: sensors interface, communication, perception, planning, and control and actuator, as shown in Figure 2-1. During the Input phase, the vehicle collects information from the surroundings, either through the different sensors or via exchanged communication between vehicles. In the Processing phase, the data gathered via the sensor interfaces and communication sources is fused in a combined stage called 'Perception'. Finally, the Output phase is where the vehicle takes actions based on the previous steps. In addition to that, new communication data is produced to be reused by other vehicles via exchanged communication. The following section explores each phase of the AVs system architecture in more detail.

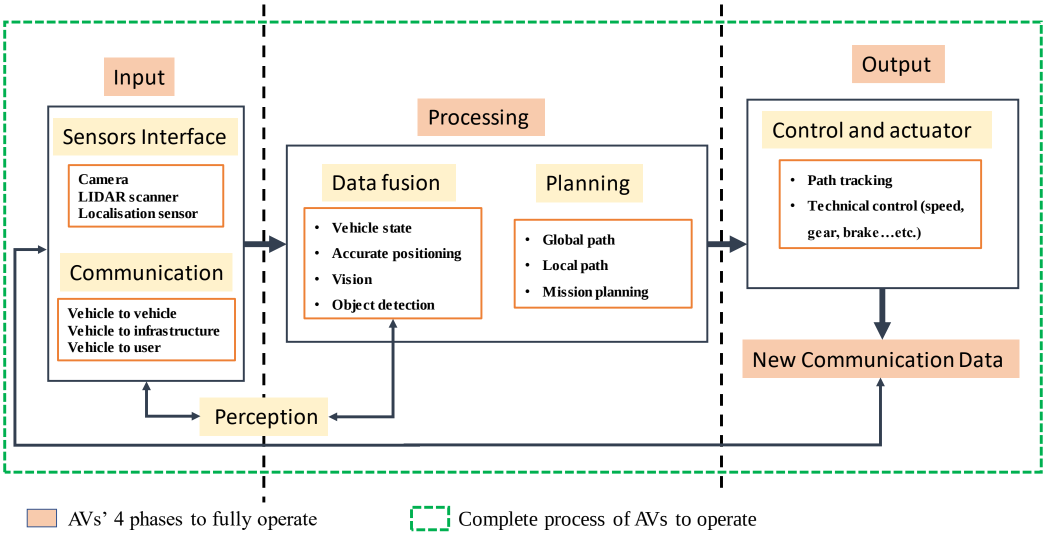


Figure 2-1. Autonomous vehicle system architecture overview

(Produced from (Kim et al., 2013; Pendleton et al., 2017; Tas et al., 2016).

2.2.1. The Input Phase

2.2.1.1. Sensors' interface

Autonomous vehicles act and make precise driving decision by sensing and detecting the surrounding environment. As a result, highly developed sensor technologies need to be developed and built before AVs can become commercially available (Anderson, 2017). These include Light Detection and Ranging (LiDAR) technology, cameras, GPS, Odometry (the use of data from motion sensors to estimate change in position over time) and ultrasound sensors, each working under a different type of frequency to capture distinct physical features (De Silva et al., 2017). An amalgamation of their outputs is required to enable the vehicle to perceive its surroundings and deal with various urban situations and scenarios, and numerous methods and approaches to addressing this have been developed. The next section provides an overview of each sensor and its utilisation in AVs.

2.2.1.2. LiDAR (Light Detection and Ranging)

LiDAR is similar to radar; however, instead of sending radio waves, the sensor launches and receive pulses of light and measures reflective objects, for instance road regions and road-edges (Zhang, 2010). In other words, LiDAR captures physical geometry by measuring the distances between objects and itself, which are reflected as points of light. High-definition LiDAR can create instant 3D maps of the environment at every movement of the vehicle (Schwarz, 2010), and this makes it ideal for the mapping systems. LiDAR can generate at least 1.3 million points of data per second, and these outputs can be interpreted through several computer programs. This has contributed significantly to the development of sensing algorithms. In fact, LiDAR features are incredibly significant in terms of range, beams, number of points, resolution and accuracy, and increasing attention is paid to LiDAR applications in various domains due to its performance in a range of conditions; indoor and outdoor, day and night (Liu et al., 2017).

The coverage limits of LiDAR to be used in AVs is highly crucial, and estimates indicate that 200 m is sufficient for time planning and response (Zhao et al., 2014). In fact, current coverage of LIDARs such as Velodyne HDL-64E are well within this range, at 120 m within its focal point (Velodyne LiDAR, 2017).

2.2.1.3. Computer vision video camera

Numerous video cameras are used to make sense of the external environment by capturing real-time status and movements in the surrounding. Image processing is the operation of getting information from input images through several techniques (Godha, 2017). A study conducted by Kho et al., (2014) used MATLAB to process the images captured by a camera. The investigation aimed to control the robot's direction movement following a green screen through images processing and frame grab intervals. Firstly, the image was blurred to eliminate any background interference (noise). Secondly, a contrast level was applied by a grayscale. Finally, this process created small white holes to be filled that isolate the square from the surroundings and make it the centroid, causing the robot to change its motion accordingly. These findings suggest that a combination of both LIDARs and cameras can be highly beneficial for the perception of the vehicle.

2.2.1.4. Localisation sensors

Autonomous navigation is about having the ability to perceive, track, map, plan and localise real-time movements (Chen & Fraichard, 2007). For AVs navigation to perform accurately in urban environments, a level of localisation is required which exceeds the available inertial guidance systems, GPS. However, using GPS and Inertial Measurement Unit (IMU) with Velodyne LiDAR can generate high-resolution ground maps which can be utilised for precise localisation (Levinson et al., 2011).

(Wang et al., 2016) believe that autonomous navigation is the crucial technology key to unlock driverless vehicles, as it provides accurate positioning to within a few centimetres. They suggested a multimodal fusion data method for precise positioning using autoregressive and moving average (ARMA) models based on GPS-IMU and Dead Reckoning (DR) navigation data. While this model achieved precise localisation, and accumulated errors resulting from DR were significantly reduced, a degradation in fusion accuracy due to satellite signal occlusion was identified (Wang et al., 2016).

2.2.1.5. Communication

Growing vehicle populations cause enormous traffic congestion that necessitates efficient traffic management systems. Research indicates that 4.2 billion hours are lost in traffic congestion each year, equivalent to one week for each passenger (Francis, 2012b), and time wasted in congestion affects productivity and contributes to air pollution (Pau, 2013). This calls for smart and innovative arrangements, and AVs offer the potential to establish a new smart traffic management system to reduce delays and pollution through information exchange (Szigeti et al., 2017). Different sensors embedded in AVs will allow vehicles to connect to their users, to other vehicles, to infrastructure, and even to pedestrians. Although vehicular communication is still in its infancy, it is believed that developing such a network will promote many future applications, and vehicles will become moving sensors, collecting information from various sources, and sharing it. Information shared could include road conditions, emergencies on the roads, location, and other data to assist in efficient traffic management, pollution monitoring, and smooth navigation (Gerla et al., 2014).

Gerla et al., (2014) suggested that the evolution of vehicular cloud computing will be the transition step to make a wide range of services available to AVs. The Internet of Vehicles (IoV) requires an open interface that all vehicles are equipped to use, enabling sensors within the vehicle to sense the environment effectively and act upon the data received. According to Kaiwartya et al., (2016), vehicular communication can be categorised under five types: vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-road signs (V2R), vehicle-to-users (personal devices) (V2P), and vehicle-to-sensors (V2S). Moreover, all the communication is referred to as V2X.

2.2.2. The Processing Phase

2.2.2.1. Perception

Human perception involves using sight, hear, taste, smell and touch to generate signals which allow us to act within our environment. Data collected from our senses (gathering and storing) is recognised and interpreted in accordance with our current knowledge (Ward et al., 2010). As a result, humans have the skills to assess and interpret a situation and compute the optimal decision to navigate (Kala, 2016). Hence, driving capability is attributed to the level of vision, perception and understanding of the surroundings. These skills and complex processes are expected to be simulated and built into AVs (Zhao et al., 2014), and perception is reckoned to be the main challenge for AVs due to the complexity of the environment and changing conditions, such as static and dynamic objects as well as weather circumstances (Luettel et al., 2012). In this context, scene analysis and understanding are critical (Y. Liu et al., 2017)

AVs rely on gathering information from the environment through several embedded sensors to inform immediate actions and long-term planning. Each sensor is responsible for acquiring data from different domains under different frequencies and circumstances, and a map of the surrounding can be generated through data fusion (Kala, 2016; Pendleton et al., 2017). For instance, using image inference, segmentation, and classification can assist in recognising and detecting road surfaces, traffic signs and obstacles, to name but a few. The significance of segmentation is discussed below.

2.2.2.2. Segmentation

Segmentation is a vital process which occurs before data fusion, with the primary goal to assist in giving meaning to the things captured by the various sensors (Pereira et al., 2016). Kala, (2016) ascertains that segmentation would be much unpretentious to have a high-resolution map in 3D of the world done by LIDARs or stereovision. For AVs to perceive and understand the surrounding environment, segmentation using either a camera (images) or a Lidar scanner (point cloud) is crucial (Liu et al., 2017). Thus, two phases, segmentation, and classification, are involved in perceiving data provided through point cloud or images (Pendleton et al., 2017). The segmentation of point cloud and images is discussed in more detail below.

2.2.2.3. 3D point cloud segmentation

Point cloud segmentation is the procedure of characterising and classifying the points into different homogenous areas that share the same properties (Nguyen & Le, 2013). Processing algorithms operating on a given point cloud help to analyse the surroundings from multiple aspects, including filtering, feature estimation and general object recognition. For instance, Point Cloud Library (PCL) is an initiative introduced to incorporate state-of-the-art algorithms in order to build up a library dealing with the most common applications for 3D perception (Rusu & Cousins, 2011). Point cloud segmentation consists of a number of processes: firstly, an edge-based method is used when an object has robust edge features, for instance, road kerb detection. Secondly, the attributes-based approach is used to cluster the points based on specific pre-determined characteristics. Thirdly, the model-based method is utilised to fit the points into predefined shapes, such as the sphere, cone, and cylinder. Fourthly, the region-based method employs criteria like Euclidian distance to cluster neighbourhood points. Finally, the graph-based process applies a graph structure to each point as nodes and connections between points on the graph (Pendleton et al., 2017).

2.2.2.4. Camera image segmentation

By contrast with point cloud, images obtained from camera videos have a greater range and more distinctive information than LiDAR. Nevertheless, the lack of in-depth knowledge in images remains as an obstacle (G. Zhao et al., 2014).

2.2.2.5. Data Fusion

According to Armingol et al., (2018), data fusion has always been related to military defence; however, with the advance of ICT, it is becoming a crucial element in many applications and industries, such as robotics and communications. Indeed, machine learning now largely depends on the progress and applications of data fusion.

Information acquired from either LiDAR or cameras has both advantages and disadvantages: LiDAR is more effective in creating 3-D images while cameras are typically 2-D. Thus, combining features derived from different sensors will contribute to higher perception levels. Fusion is enabled either by centralised or decentralised approaches. In a centralised approach, the blending is happening on the pixel level, whereas the decentralised method classifies each sensor data separately and then results are combined (Salahshoor et al., 2008). For instance, a study conducted by Giering et al., (2015) aimed to increase image-level accuracy by providing a way to fuse patch-level and image-level predictions. The study used data from a video camera and LiDAR. Each video frame has channel data that consists of Grayscale or RGB information in addition to optical flow (U, V); hence, the depth information is obtained from LiDAR (L) sensor. Deep convolutional neural networks (DCNNs) and kernel filter were executed to fuse (R, G, B, Gr, L, U, V) to support enhanced object recognition.

2.2.2.6. Object recognition

Object recognition capacity is the key to AV safety, as accurate recognition of objects (vehicles, pedestrians, animals, traffic signals and bicyclists) and their trajectories is required for prudence in vehicle's decision-making (Uçar et al., 2017). The car is equipped with several sensors to enable this to happen. Figure 2-2 illustrates an example of an object recognition process.

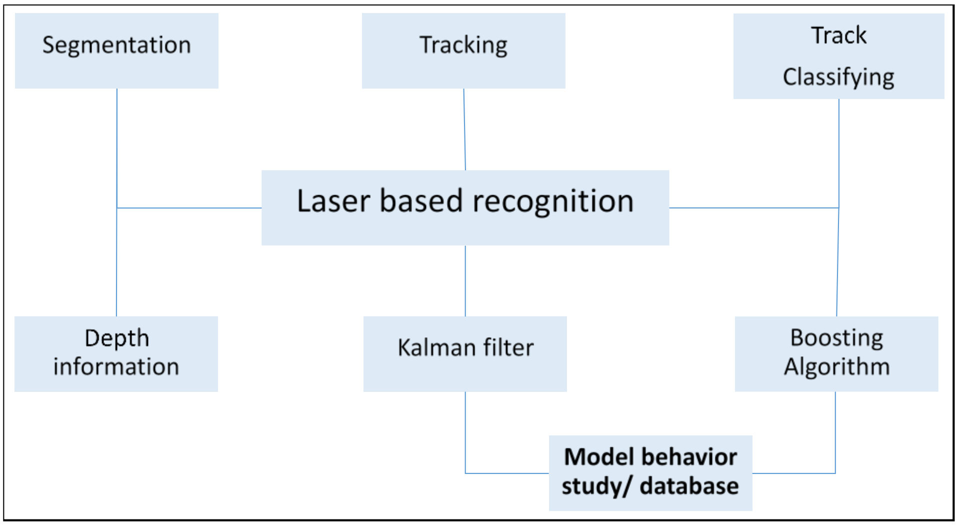


Figure 2-2. Example of an object recognition process (Teichman & Thrun, 2011).

However, Teichman & Thrun, (2011) believe that other challenges are still to be tackled, such as construction zones (traffic cones, construction equipment and workers holding signs) which will require advanced tracking algorithms and recognition capabilities that can encode motions, shapes and sizes of objects. One way to achieve this is to study the behavioural models of these objects in order to enable for AVs to have the ability to anticipate their actions (Teichman & Thrun, 2011).

Using RGB images and LiDAR point cloud is another way for 3D object detection. Chen et al., (2017) used a combination of LIDAR point cloud and RGB images to create a sensory-fusion framework that can generate 3D object proposals (boxes) as shown in Figure 2-3. The study proved that utilising such a combination showed 25% and 30% greater precision on 3D localization and 3D detection tasks compared to other approaches at the time.

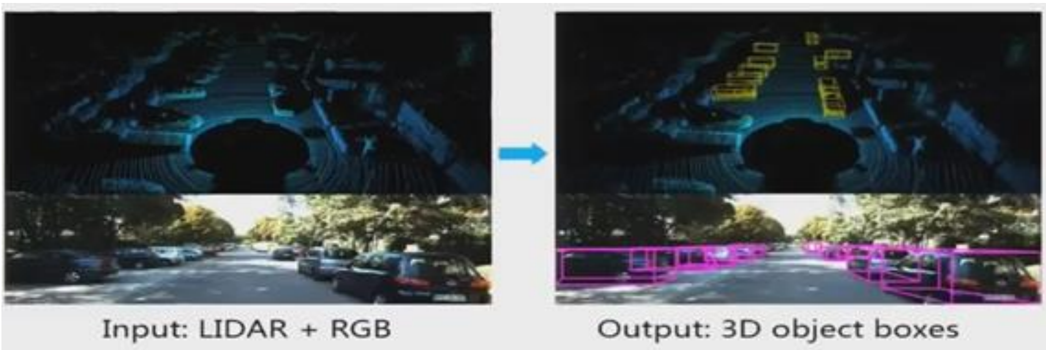


Figure 2-3. 3D object detection using sensor fusion of LiDAR and RGB (Xiaozhi et al., 2017).

2.3. Barriers to Full Adoption of Autonomous Vehicles

Analysis of recent literature suggests that the full adoption of AVs depends on various key barriers being overcome. Although the majority of academic research about AVs has been technically focused (Skeete, 2018), Martínez-Díaz & Soriguera, (2018) stated that we must start designing cooperative traffic management strategies in order to overcome technological barriers. As a result, this research included a systematic study to identify the obstacles that AVs are facing. The methodology for this part of the study is explained in Chapter 3 (See section '3.9.1 Phase I'). This section presents a synthesis of the key findings that resulted from the four stages analysis carried out on 140 papers published between 2012 and 2019..

Figure 2-4 depicts the critical barriers to full AV adoption found in the literature using content analysis and the relations between them. The barriers identified were: 1) Safety; 2) User acceptance and reactions; 3) Certification, regulations and ethics; 4) Accurate positioning and mapping; 5) Computer software and hardware; and 6) Communication Systems (Networks). These were then grouped under four aspects: Technical, Social, Urban and Legislative and clustered into two main categories: ICT and User/Government perspectives. These were further grouped into six sub-clusters, including the factors that contribute to each barrier. These categories and the barriers associated with them are discussed in more detail below.

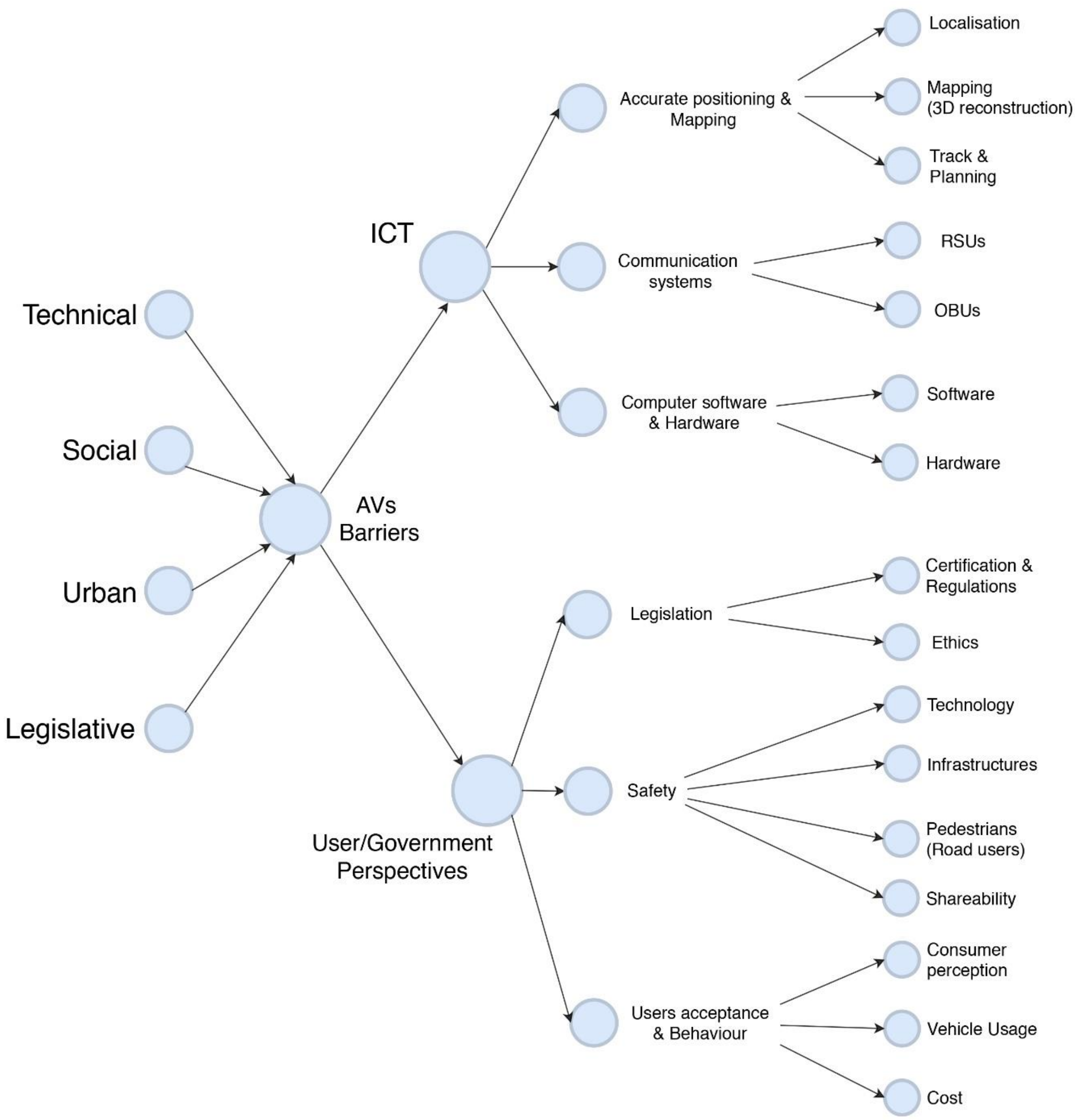


Figure 2-4. Key barriers preventing full adoption of AVs and their interrelatedness (Bezai et al., 2021).

Table 2-1. Details of the sources consulted to identify and explore the barriers (Bezai et al., 2021).

Barriers	Scholars, Government Departments and Research Organisations		
	2019	2018	2012-2017
1. Safety	Ackermann et al. (Ackermann et al., 2019) Aguiléra (Aguiléra, 2019) Combs et al. (Combs et al., 2019) Magnusson et al. (Magnusson et al., 2019)	Alessandrini, Holguin and Parent (Alessandrini et al., 2018) Alfonso et al. (Alfonso et al., 2018) Armingol et al. (Armingol et al., 2018) Department for Transport (Department for Transport, 2018) Gopalswamy and Rathinam (Gopalswamy & Rathinam, 2018) Grush and Niles (Grush & Niles, 2018a) Jiménez (Jiménez, 2018) Nazari, Noruzoliaee and Mohammadian (Nazari et al., 2018) Simoni et al. (Simoni et al., 2018) Skeete (Skeete, 2018) Straub and Schaefer (Straub & Schaefer, 2018)	Alessandrini et al. (Alessandrini et al., 2015) Bell (Bell, 2017) Fagnant and Kockelman (Fagnant & Kockelman, 2015) Fagnant and Kockelman (Fagnant & Kockelman, 2016) Francis (Francis, 2012a) Kho, Abdulla and Yan (Kho et al., 2014) Litman (Litman, 2017b) Maurer et al. (Maurer et al., 2016) Perch (Perch, 2014) Roberts (Roberts, 2017) Santi et al. (Santi et al., 2014) wsp (wsp, 2016)

			Villagra et al. (Villagra et al., 2018)	
2.	**User acceptance and reaction**	Agarwal, Kumar and Zimmerman (Agarwal et al., 2019) Aguiléra (Aguiléra, 2019) Alfonso et al. (Alfonso et al., 2018) Boutueil (Boutueil, 2019) Cohen and Hopkins (S. A. Cohen & Hopkins, 2019) Combs et al. (Combs et al., 2019) Webb, Wilson and Kularatne (Webb et al., 2019)	Aarhaug and Olsen (Aarhaug & Olsen, 2018) Anania et al. (Anania et al., 2018) Buckley, Kaye and Pradhan (Buckley et al., 2018) De Bruyne and Werbrouck (De Bruyne & Werbrouck, 2018) Ferrero et al. (Ferrero et al., 2018) Gheorghiu and Delhomme (Gheorghiu & Delhomme, 2018) Grush and Niles (Grush & Niles, 2018b) Joiner (Joiner, 2018) Kaur and Rampersad (Kaur & Rampersad, 2018) Kim (S. Kim, 2018) Kolarova et al. (Kolarova et al., 2018) Liljamo, Liimatainen and Pöllänen (Liljamo et al., 2018) Meinlschmidt, Stalujanis and Tegethoff (Meinlschmidt et al., 2018)	Alves (Alves, 2017) Babbar and Lyons (Babbar & Lyons, 2017) Bansal and Kockelman (Bansal & Kockelman, 2017) Nath (Nath, 2017) Wadud (Wadud, 2017) Bansal, Kockelman and Singh (Bansal et al., 2016) Nordhoff, van Arem and Happee (Nordhoff et al., 2016) Fagnant and Kockelman (Fagnant & Kockelman, 2015) Kyriakidis, Happee and de Winter (Kyriakidis et al., 2015)

			Molnar et al. (Molnar et al., 2018) Winter et al. (Winter et al., 2018) Panagiotopoulos and Dimitrakopoulos (Panagiotopoulos & Dimitrakopoulos, 2018) Straub and Schaefer (Straub & Schaefer, 2018) Xu et al. (Z. Xu et al., 2018)	
3.	**Certification/regulations and ethics**	Narayanan (Narayanan, 2019)	Anania et al. (Anania et al., 2018) Bichiou and Rakha (Bichiou & Rakha, 2018) Congressional Research Service (Congressional Research Service, 2018) De Bruyne and Werbrouck (De Bruyne & Werbrouck, 2018) Kröger, Kuhnimhof and Trommer (Kröger et al., 2018) Li et al. (S. Li et al., 2018) López-Lambas (López-Lambas, 2018)	Chen et al. (D. Chen et al., 2017) Conceição, Correia and Tavares (Conceição et al., 2017) Bonnefon, Shariff and Rahwan (Bonnefon et al., 2016) Schellekens (Schellekens, 2015)

		Noy, Shinar and Horrey (Noy et al., 2018) Ruggeri et al. (Ruggeri et al., 2018) Straub and Schaefer (Straub & Schaefer, 2018) Evas et al. (Evas et al., 2018)	
4. Accurate positioning and mapping		Hongyu et al. (Hongyu et al., 2018) Konrad et al. (Konrad et al., 2018)	Li et al. (J. Li et al., 2016) Wang, Deng and Yin (S. Wang et al., 2016) Katrakazas et al. (Katrakazas et al., 2015) Signifredi et al. (Signifredi et al., 2015) Kala and Warwick (Kala & Warwick, 2013) Kim et al. (J. Kim et al., 2013) Zhang et al. (S. Zhang et al., 2013) Levinson et al. (Levinson et al., 2011) Chen and Fraichard (G. Chen & Fraichard, 2007)
5. Computer software and hardware	Loukas et al. (Loukas et al., 2019) Marletto (Marletto, 2019)	Armingol et al. (Armingol et al., 2018)	Pendleton et al. (Pendleton et al., 2017)

		Xu and Duan (L. Da Xu & Duan, 2019)	Bechtsis et al. (Bechtsis et al., 2018) Bichiou and Rakha (Bichiou & Rakha, 2018) De La Torre, Rad and Choo (De La Torre et al., 2018) Guanetti, Kim and Borrelli (Guanetti et al., 2018) Marks (Marks, 2018) Mullins et al. (Mullins et al., 2018) Noy, Shinar and Horrey (Noy et al., 2018)	Sarikan, Ozbayoglu and Zilci (Sarikan et al., 2017) Wadud (Wadud, 2017) Aria, Olstam and Schwietering (Aria et al., 2016) Kalra and Paddock (Kalra & Paddock, 2016) Maurer et al. (Maurer et al., 2016) Tas et al. (Tas et al., 2016) Gallello (Gallello, 2013) Kim et al. (J. Kim et al., 2013)
6.	**Communication Systems (Networks)**	Arena and Pau (Arena & Pau, 2019) Gao and Xin (Gao & Xin, 2019) Hou and Gao (Hou & Gao, 2019) Liu et al. (X. Liu et al., 2019) Rubin et al. (Rubin et al., 2019) Rueckelt et al. (Rueckelt et al., 2019) Wahid et al. (Wahid et al., 2019)	Abbasi and Shahid Khan (Abbasi & Shahid Khan, 2018) Alfonso et al. (Alfonso et al., 2018) Atzori et al. (Atzori et al., 2018) Banks et al. (Banks et al., 2018) Chen et al. (M. Chen et al., 2018) Hussain et al. (Hussain et al., 2018) LI et al. (LI et al., 2018)	Aria, Olstam and Schwietering (Aria et al., 2016) Sucasas et al. (Sucasas et al., 2015)

Saini, Saad and Jaekel (Saini et al., 2018)

Shin et al. (Shin et al., 2018)

Song et al. (Song et al., 2018)

Wang et al. (Y. Wang et al., 2018)

Yang and Deng (Yang & Deng, 2018)

Zhao et al. (W. Zhao et al., 2018)

Zhou et al. (Zhou et al., 2018)

2.3.1. ICT-related barriers

A number of barriers emerged from the literature relating to the highly complex technology involved in AVs and need for further research to develop and enhance AV systems architecture. This section presents barriers relating to computer software and hardware, communication Systems (V2X/VANETs), and accurate positioning and mapping, and considers the solutions required to address them.

2.3.1.1. Computer software and hardware (sensors)

Guanetti et al., (2018) stated that the idea of AVs has been around for a century, but that innovative advances in sensing technologies and computing have now made them possible. In recent years, computers have become important parts of vehicles, taking care of tasks such as cruise control (Bichiou & Rakha, 2018). However, not only do cars have to sense all the surrounding areas, but they must also understand what they are sensing. According to Noy et al., (2018), the complication of AVs is that there are currently no fundamental or sophisticated algorithms that can cover all the possible scenarios, which indicates that there is still a lot to learn about automated technologies. Hence, for AVs to perform as desired, a significant development in algorithms is required (Bichiou & Rakha, 2018), so they can decide what to do and act immediately (Maurer et al., 2016). This will involve two fundamental elements: developing software and hardware (sensors). Figure 2-5 illustrates the factors involved and suggested solutions or actions are provided in the green box.

In respect of the potential solutions, very advanced computer software and hardware is needed to process the information coming from the various sensors, LiDARs, and cameras for the fusion process that assists AV decision-making. At full adoption of AVs, it is anticipated that accidents caused by human errors will be effectively eliminated; however, software and hardware related hazards could increase (Wadud, 2017). However, (Loukas et al., 2019) believe that intrusion detection systems (IDSs) can help to defend against cybersecurity risks. Hence, these kinds of approaches need to be designed into AVs and networks, and that also presents a challenge. These challenges and potential solutions are discussed in more detail below.

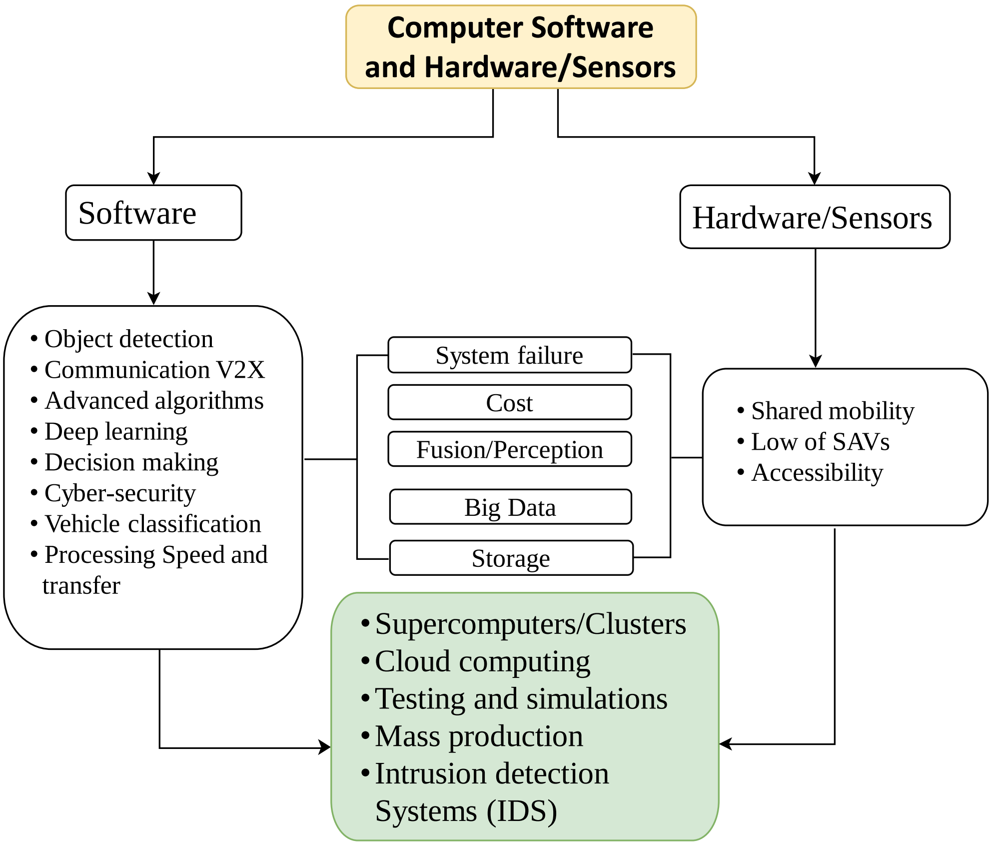


Figure 2-5. Factors that impact computer software and hardware (sensors) (Bezai et al., 2021).

In terms of the AV system architecture (See 2.2) the processing phase is where most of the software is needed. According to (Pendleton et al., 2017), AV software systems can be comprehensively grouped into three classifications: perception, planning and control, and AVs will always depend on fusion data to assure reliability (Armingol et al., 2018). However, software and hardware are human-made and this subject to potential failure which could lead to catastrophe on the roads (Pendleton et al., 2017). Therefore, it has been suggested that AVs require a new system architecture with a centralised supercomputer to manage the data generated from all the sensors (Aria et al., 2016). Furthermore, AVs are expected to deal with diverse data about road conditions, obstacles, communications and many others. Thus, enormous amounts of data are collected and processed every second, and the rate of transfer amongst AVs will be up to speeds 1GB per second (Gallello, 2013); this requires powerful computers and significant data storage hardware.

Over 250 million lines of code need to be programmed to build AVs software, and this can vary from one AV category to other (Marks, 2018). Figure 2-6 illustrates the various technologies within AVs which generate data which must be processed by a powerful computer. According to (L. Da Xu & Duan, 2019), processing big data like this is beyond the capacities of the PCs which usually utilised; hence it requires super-PCs or clusters of PCs.

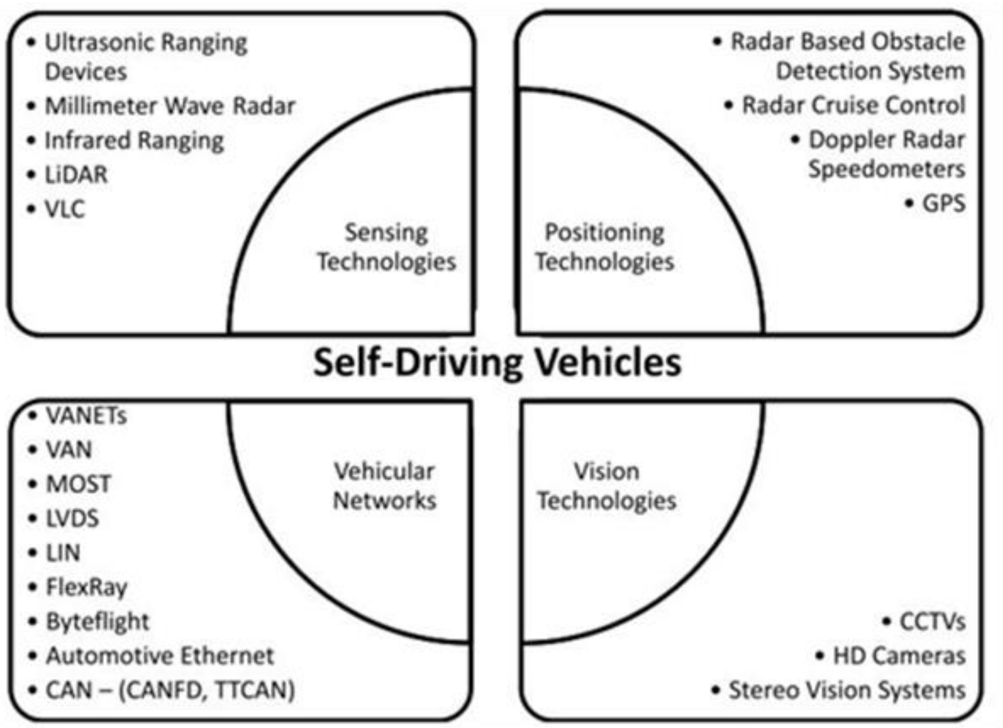


Figure 2-6. Technologies needed to be embedded in AVs (De La Torre et al., 2018).

In addition, (Sarikan et al., 2017) argue that vehicle classification is significant for overall IT system efficiency, although software-based classification has a significant time constraint they are more robust than hardware-based classification. As a result, the former demands rugged computers.

Another barrier is that both software and hardware need extensive system testing before being applied in the real world (Kalra & Paddock, 2016; Mullins et al., 2018) and the process of testing and obtaining legal approval requires a considerable amount of time. Guanetti et al., (2018) argue that selecting suitable testing scenarios that reflect the real world is highly significant. For instance, Google started AV testing in 2009 and over 2 million miles have now been driven on actual streets (Marletto, 2019) but there is still ongoing to testing to develop how AVs can be deployed. Equally, simulation tools can also play a critical role in the integration of AVs and CAVs, especially in terms of assessing their performance and identifying the facilities (infrastructure) needed to support them (Bechtsis et al., 2018). Thus, highly customised simulation tools are also a necessity, and these take time to develop.

2.3.1.2. Communication systems (V2X and VANETs)

With the advent of the IoT, AVs are at the centre of intelligent transport systems (ITS), and they are already equipped with innovative technologies that permit them to establish communications and cooperation with different units, including other vehicles' OBUs and RSUs, through short-range wireless networks (Atzori et al., 2018). Figure 2-7 shows the various factors that affect AV communications with RSUs and OBUs.

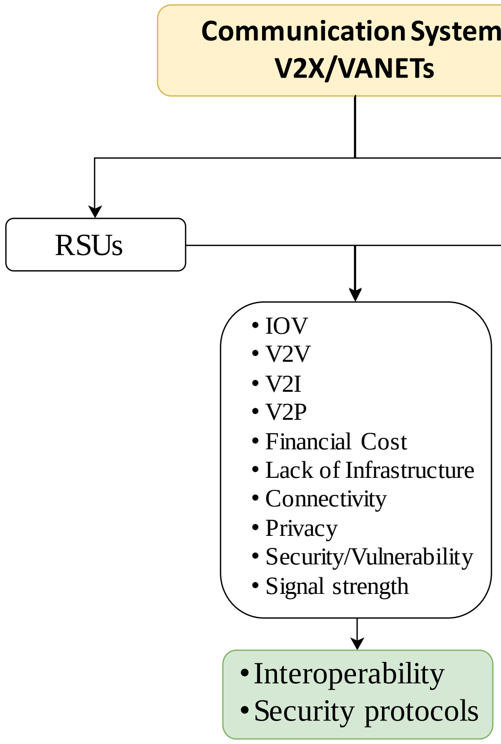


Figure 2-7. Factors that impact AV communication (Bezai et al., 2021).

The increasing interest in vehicular communication has led to the emergence of the Internet of Vehicles (IoV). This is becoming the critical empowering technology to implement future AVs and that can be achieved through Vehicular Ad-hoc Networks (VANETs). The latter are an offshoot of mobile ad-hoc networks (MANETs) and have become the essential building blocks for ITS (Abbasi & Shahid Khan, 2018; Alfonso et al., 2018; M. Chen et al., 2018; Hussain et al., 2018). VANETs are used to provide communication between vehicle and different V2X nodes: these can be classified as follow: Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and Vehicle-to-Pedestrians (Users) (V2P) (Aria et al., 2016; Banks et al., 2018; Rubin et al., 2019; W. Zhao et al., 2018)

Vehicular communication will result in a better ITS application. Nevertheless, (Arena & Pau, 2019) believe that the primary hindrance to its implementation is the financial cost because currently just a small part of overall road infrastructure is ready for V2X; thus, significant economic resources are needed. In addition, data transmission within the network is a challenging task due to high mobility and continual location changes (Rueckelt et al., 2019; Shin et al., 2018; Zhou et al., 2018). Since the urban driving environment is complex, building a reliable VANET also depends on sufficient signals strength amongst its receiver and connectivity (LI et al., 2018). A further concern in employing VANETs is the comprise of privacy and security because VANETs can expose critical information about the vehicles (Saini et al., 2018). Numerous scholars have discussed this issue and proposed various solutions (Gao & Xin, 2019; Hou & Gao, 2019; X. Liu et al., 2019; Song et al., 2018; Sucasas et al., 2015; Wahid et al., 2019; Y. Wang et al., 2018). For instance, Yang & Deng, (2018) suggested a privacy protection mechanism that permits vehicles to utilise pseudonyms periodically when exchanging data in order to disrupt the consistency of attackers' tracking.

2.3.1.3. Accurate positioning and mapping

Wang et al., (2016) believe that autonomous navigation is the crucial technology key for driverless vehicles, as it provides accurate positioning to within a few centimetres. According to Li et al., (2016), due to recent competition in the development of self-driving cars, a large number of methods and algorithms have been created in the fields of machine learning, image processing, localisation, decision-making, and communication which can assist in autonomous navigation. Figure 2-8 illustrates the key factors affecting AV positioning and mapping.

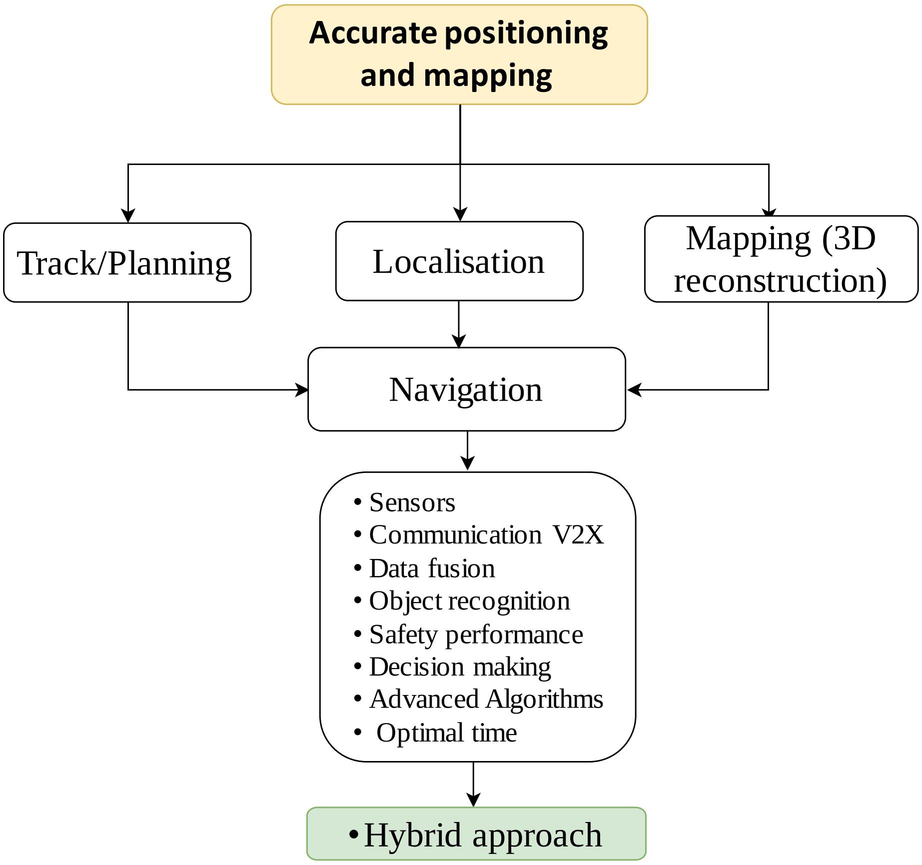


Figure 2-8. Factors that impact accurate positioning and mapping (navigation) (Bezai et al., 2021).

As discussed above, autonomous navigation is about perceiving, tracking, mapping, planning and localising real-time movement (Chen & Fraichard, 2007). Thus, for AVs to perform effectively, real-time navigation and accurate positioning are key. GPS and IMU with LiDAR can now generate high-resolution ground maps for precise localisation (Levinson et al., 2011), a multimodal data fusion model for precise positioning using ARMA models has been suggested (Wang et al., 2016), and Global Navigation Satellite Systems (GNSS) are becoming a preferred options for delicate positioning (Konrad et al., 2018); however, more research needs to be done on AV navigation.

Path planning is critical for AV navigation (Hongyu et al., 2018; Kala & Warwick, 2013; Katrakazas et al., 2015; Signifredi et al., 2015; S. Zhang et al., 2013). Not only are AVs required to move from point A to B in real-time but also to achieve high safety performance, accuracy in positioning, precise object recognition, and to make decisions which comply with traffic laws (Li et al., 2016). Therefore, path planning algorithms are increasingly being adapted to address the complexity of urban traffic scenarios because these algorithms are run in parallel with data fusion of different 3D scanners, navigation systems and cameras.

Path planning algorithms are responsible for vehicle mode decisions, reaching the destination without collision, and acceleration and deceleration (J. Kim et al., 2013). They are constituted of mission planner, optimal path and longitudinal motion planner elements, and methods currently in use include Voronoi Diagrams, Fuzzy logic, VFH (Vector Field Histogram) and graph search (Katrakazas et al., 2015). However, Li et al., (2016) suggest that the best option is to use a hybrid path planning system which is achieved by local and global preparation. The former is to create an optimal path avoiding obstacles, whereas the latter is to maintain the vehicle by smoothing the trajectory (Signifredi et al., 2015).

This section has identified a number of technical barriers relating to the adoption of AVs. However, driverless vehicles will also need to gain social acceptance if they are to be widely adopted; appropriate legislative frameworks will also need to be put in place. These social and legislative barriers are discussed in more detail below.

2.3.2. User perceptions and legislative barriers

The second set of barriers identified in this study relate to public acceptance of AVs, the behaviour of end-users and the requirement for government support. Hence, this category presents the following barriers: safety, user acceptance and behaviour, and legislation, and considers the solutions required to address them.

2.3.2.1. Safety

Safety has been identified as the most significant obstacle regarding the implementation of AVs and has been widely discussed in the literature (See Table 2-1). Research suggests that tackling the safety barrier depends on addressing four key domains: Pedestrians (road users), Infrastructure, Shareability, and Technology. The relationship between these domains is set out in Figure 2-9, and the main factors associated with them are identified. These domains are discussed in more detail below and possible solutions to address the factors listed in Figure 2-9 are identified. As regulation is an overarching requirement, it is discussed separately in the later section on legislation (See Section 1.3.2.3). Users' perceptions of safety with respect to AVs is discussed in Section 1.3.2.2.

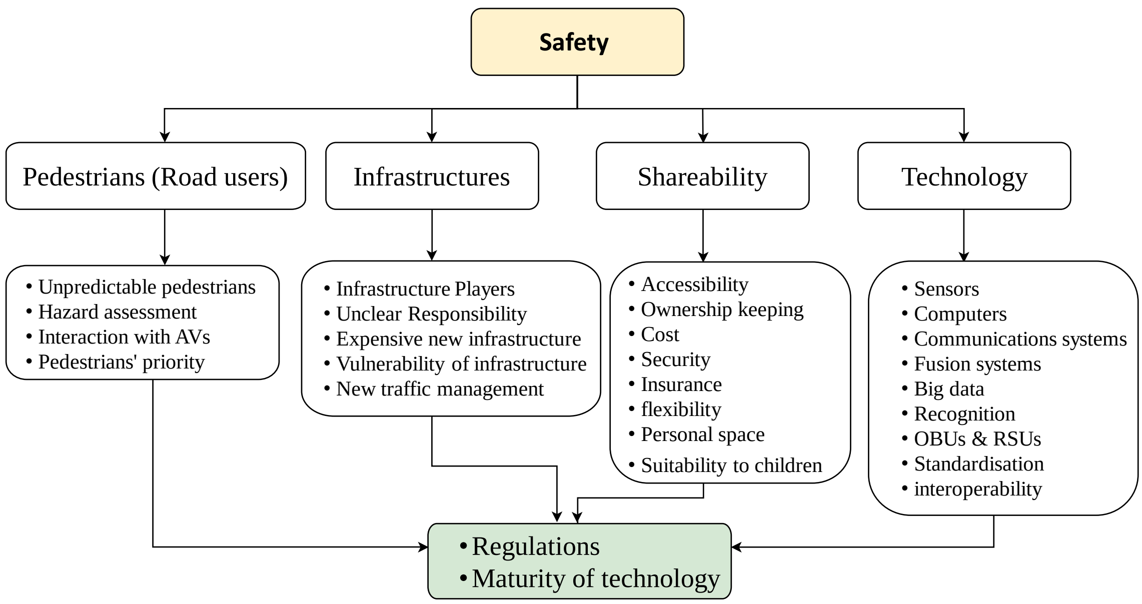


Figure 2-9. Various factors that impact Safety (Bezai et al., 2021)

a) Pedestrians (Road users)

Statistics show that in Britain, five fatalities and about 66 injuries occur every day on the roads (Roberts, 2017) with 26% of road deaths being of pedestrians (Department for Transport, 2018). Many experts anticipate that AV technologies will significantly decrease pedestrians' fatalities; however, as Bell, (2017) stressed, there will always be unpredictable people in the streets who cannot accurately assess hazards. Urban areas therefore constitute a particular challenge, as road users can be vulnerable and they must interact with AVs in different ways (Ackermann et al., 2019). Thus, a well-designed and integrated system must prioritise the safety of pedestrians (Maurer et al., 2016). A study by Combs et al., (2019) analysed pedestrian fatality reports in the U.S. and concluded that 3,386 transportation-related pedestrian fatalities out of 4,241 could have been avoided if an AV equipped with pedestrian sensors had been employed, a reduction in deaths of around 80%. Equipping AVs with such sensors could bring great benefits yet, given the costs associated with this technology at present, it might be considered too costly for widespread application.

b) Infrastructure

Implementing infrastructure that enables vehicle cooperation through wireless communication systems will improve safety and efficiency. Effective vehicular communication allows high-level behaviours (Villagra et al., 2018); platooning is one of these behaviours, and it represents one of the key benefits of AVs (Kho et al., 2014). However, this will require the implementation of new traffic management strategies by traffic authorities to extend sensing capabilities and the exchange of information and further research to develop the requisite infrastructure. Villagra et al., (2018) believe that the complexity and challenging scenarios within our urban areas necessitate specific research in the following domains: big data, sensing technologies, IoT, Cloud computing, and AI, and the required infrastructure to manage them. Introducing infrastructure players will also leverage and re-balance responsibilities and help to ensure the safety of AVs.

For instance, ARTS is one of the systems suggested by Alessandrini et al., (2018) in the cityMobile 2 project which can be implemented in urban areas to improve road use and transportation. In addition, Volvo have suggested a magnetic road project which involves the use of magnets installed on the road surface to guide and keep the vehicle in its lane and determine its exact position (Perch, 2014). Although significant costs are attached to infrastructure upgrades, the cooperative driving which can be achieved using the updated infrastructure will assist in better road management, reduce the frequency with which maintenance is required, and reduce the need for new roads to be built (wsp, 2016).

c) Shareability

There is a consensus in the literature that the benefits of AVs can be maximised when they are shared. A study by Fagnant & Kockelman, (2016) revealed that each shared AV could replace roughly 11 private cars, with the potential to reduce car ownership, thereby decreasing traffic congestions and urban pollution. In addition, a study in New York, showed that 95% of taxi trips taken in the city could be shared (Santi et al., 2014), and shared mobility is expected to alter urban transportation significantly when integrating adaptable public travel modes compared to private (Nazari et al., 2018). Simoni et al., (2018) believe that Shared Autonomous Vehicles (SAVs) will enhance people's mobility, the traffic conditions they experience and their behaviour. However, the principal obstacles to achieving these benefits are related to safety concerns, most notably factors such as risk of attacks and accidents insurance problems, and lack of flexibility in schedules and coordination (Aguiléra, 2019). Moreover, Grush & Niles, (2018a) identified specific concerns relating to the safety of children, with parents believing that shared or on-demand vehicles will not be suitable or sanitary, or fitted with appropriate rear seating. They also found that personal space enjoyment and the illusion of being in control are barriers to shared use of vehicles (Grush & Niles, 2018a).

d) Technology

Handing over control to the technical systems within AVs has the potential to improve safety, notably through V2V communication (Fagnant & Kockelman, 2015; Litman, 2017a). Various sensors embedded in the car are expected to scan the environment and form an active safety system; however, some of these (notably cameras) can be limited by the road area visibility (Alfonso et al., 2018). Therefore, fusing the data obtained from several sensors plays a critical role in enhancing AV detection capacity in order to deliver more reliable road safety. This is pivotal in overcoming the limitations of a single sensor (Armingol et al., 2018).

Another way that ICT can maximise AV safety is through the knowledge of road conditions that is achieved by employing sensors reporting real-time data about the road conditions; this also has the potential to inform decisions about road maintenance (Armingol et al., 2018). For instance, LiDAR scanners can detect potholes and friction and communicate this to stakeholders for actions, making travel safer and more efficient because the data can be utilised to improve maintenance, such as salting and pothole repairs (Magnusson et al., 2019). As a result, ICT applications are decisive in attaining safety, through both the data collected to inform decisions within the vehicle, and that shared with other stakeholders.

According to Alfonso et al., (2018) in order for users to receive all the required information related to traffic and safety conditions, a hybrid communication approach is required, integrating both On-Board Unit (OBU) and Road-Side Unit (RSU) outcomes. As a result, some form of standardisation to facilitate such communication is required. The European Commission considers standardisation will bring various benefits, particularly in terms of data access, but interoperability is an important obstacle to overcome to ensure functionality (Skeete, 2018). Therefore, Straub & Schaefer, (2018) claim that there is a necessity to develop common technical standards to deal with interoperability and safety.

2.3.2.2. User acceptance and behaviour

Adopting a new technology always has been influenced by the mindset and attitude of the people, and this will affect the extent to which the benefits associated with AVs are achieved

(Liljamo et al., 2018). Public opinion also will determine the way that vehicle manufacturers need to develop their market (Kyriakidis et al., 2015). According to Anania et al., (2018), many studies have demonstrated that participants are not keen to utilise driverless technologies. A survey conducted by Bansal & Kockelman, (2017) revealed that a significant proportion of respondents were unwilling to ride in AVs, either for a short distance (42.5%) or a long distance (40%). Such unwillingness may be explained because of the users' uncertainty and distrust in automation (Joiner, 2018; Winter et al., 2018). Thus, the lack of public trust is one of the main barriers to the full adoption of AVs. It has been suggested that trust can be imputed in variables such as reliability, performance expectancy and security (Kaur & Rampersad, 2018), and there is an assumption that people who already engage with technology are more likely to feel positive about AVs and trust them (Molnar et al., 2018).

The precise determinants of users' acceptance of AVs are still ambiguous, and there is a lack of a conceptual model to clarify the motives of recognition acceptance (Nordhoff et al., 2016). However, the majority of these determinants can be grouped into three categories: (i) perception, (ii) vehicle usage, and (iii) cost. In addition, ethical issues regarding AVs have a strong influence on user acceptance. For instance, people will typically prefer to ride in AVs that prioritise passenger safety in any situation (Cohen & Hopkins, 2019). These categories and the factors associated with them are presented in Figure 2-10.

a) Consumer perceptions (including awareness, safety concerns, and reliability)

Many studies have been carried out in an attempt to understand users' perception of AVs. Meinlschmidt et al., (2018) found that the present comprehension of human psychobiology in relation to automated driving is still constrained and limited; however, feeling a high level of safety has been identified as a vital precondition for people to accept AVs (Xu et al., 2018).

Increasing the sense of security, especially in sharing services, has been found to enhance users' acceptance. For instance, including features such as an "Alert button" in ride ordering apps can help users communicate with relatives, emergency services, or the police in case of accidents or other serious incidents (Boutueil, 2019).

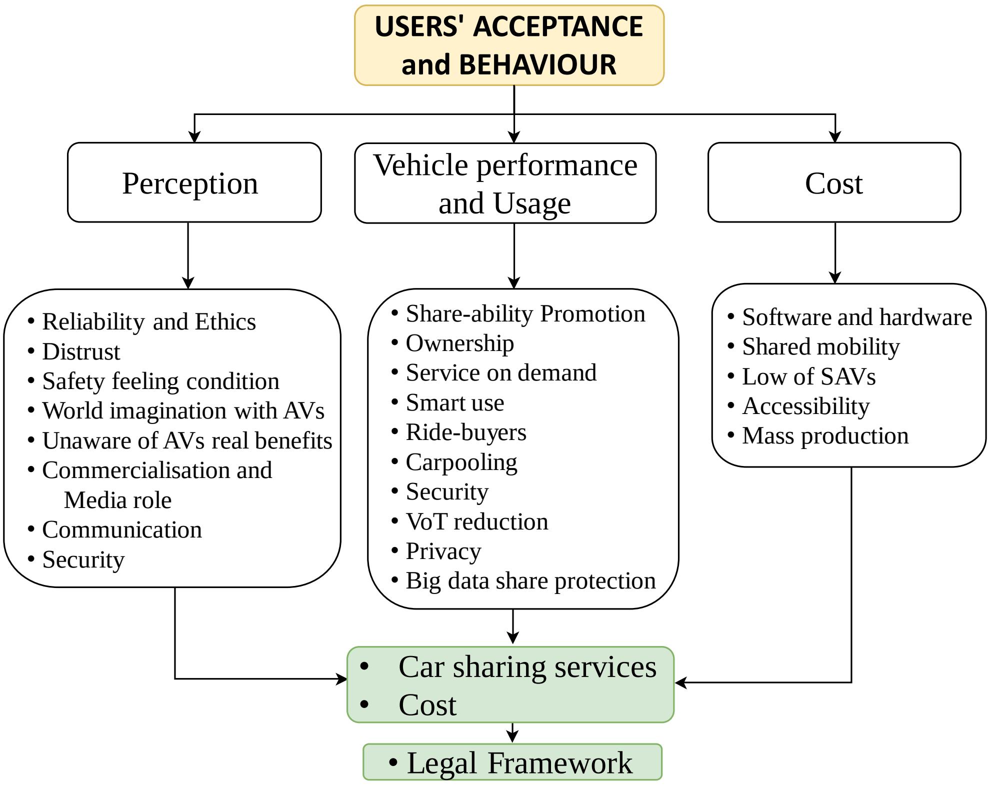


Figure 2-10. Various factors that are impacting users' acceptance of AVs (Bezai et al., 2021).

In addition, Bansal & Kockelman,(2017) survey exploring Americans' long-term AV adoption found that around 50% of respondents were not willing to pay to get level 3 and 4 automation. People are more likely to adopt AVs if they know more about their real benefits; however, many of the survey respondents could not imagine a world with AVs, and they expressed safety and reliability concerns towards these technologies. By contrast, a study by (Buckley et al., 2018) employing a qualitative examination of drivers using AVs, found that participants did not have the same safety reservations, although some of them reported that they required more practice before driving them out on real roads. Enhancing quality of service also affects the perception of AVs as a transport mode, notably the travel-time reliability, which is considered very influential in shaping users' travel behaviour. This indicator can also be used to measure the performance of AVs, especially in urban settings (Aguiléra, 2019).

Panagiotopoulos & Dimitrakopoulos, (2018) argue that as AVs have not yet been commercialised, most potential end-users are not familiar with these technologies, and this affects their perception of AVs. As a result, the media can play a significant role in shaping end-user's opinion of AVs. Anania et al., (2018) found that consumers are less likely to use AVs if they are portrayed in a negative light in the media. By contrast, if they are advertised positively, particularly in terms of efficiency and safety, consumers are more likely to be persuaded to use them. Furthermore, Joiner, (2018) suggested that libraries can also play an important part in promoting driverless technologies, providing access to information about AVs, such as online and printed resources. This can help raise awareness about the benefits associated with them as well as the legislative and insurance requirements.

The question of who should be held responsible in case of an accident or damage caused by an AV is also highly significant. The answer will have profound impacts on the commercialisation and use of self-driving vehicles (De Bruyne & Werbrouck, 2018). In the case of conventional cars, drivers are usually blamed for their mistake in case of accidents. However, in an AV scenario, the car drives itself, so passengers will not be held responsible in the same way. This may encourage the adoption of AVs once clear, robust processes are in place to determine the responsible party in case of accidents (Kaur & Rampersad, 2018).

b) Vehicle usage (including shareability, ownership and privacy)

The definition of private and commercial transport is changing due to the introduction of on-demand ride services such as Uber and Lyft. However, in the scenario of AVs, critical questions must be addressed such as how the market will be organised and will AVs be owned personally or run by private companies or integrated into public transport (Aarhaug & Olsen, 2018). Alves, (2017) argues that, while issues like congestion and pollution will not vanish with AVs, smart use of driverless vehicles can lead to sustainable mobility, and Fagnant & Kockelman, (2015) believe that AVs taxis will become a viable alternative to personal cars, thereby minimising ownership demands. If AV usage is shown to enhance shared mobility, this is likely to have a positive influence of user adoption.

People in the suburbs and urban areas are expected to respond to AVs in different ways, and Grush & Niles, (2018b) have forecast that private AVs will reach a high peak before shifting to various type of shared transport-on-demand. However, they argue that it is important to consider how to change users into ride-buyers to reduce ownership rather than just focusing on promoting AVs (Grush & Niles, 2018a). Carpooling has been identified as one transport mode that policy-makers should encourage and integrate into public transportation in order to support long-term sustainable transport (Gheorghiu & Delhomme, 2018). Although this recommendation was based on non-autonomous vehicles, this form of shareability could easily be extended to AVs. In addition, (Ferrero et al., 2018) believe that the widespread use of car-sharing services is encouraging citizens to move away from car ownership to service on demand. AVs have the potential to reform the whole sharing services concept, providing not only opportunities to share a car but also cargo spaces (Kim, 2018). Reducing users' travelling time, thereby increasing the value of time (VoT), and providing new mobility services, also has the potential to affect mode choice and passenger behaviour (Kolarova et al., 2018). Thus, aspects of ownership and shareability of AVs will have significant impacts on the acceptance of users.

Privacy will also constitute a vital issue in respect of users' acceptance of AVs. Studies have demonstrated that information gathered by AVs through V2X communication can be misused, with fatal consequences, and this presents a significant concern for users (Agarwal et al., 2019). Alfonso et al., (2018) suggested that the willingness of end-users to share the data coming from their vehicle will depend on data protection principles that impose compliance with a legal framework to implement a cooperative intelligent transport system (C-ITS). In addition, violation data protection protocols must be embedded at the design stage of AVs.

c) High costs associated with AV technology

The high costs associated with AVs have been identified as a barrier to their widespread adoption, despite their long lifespan (Liljamo et al., 2018), notably because integrating sensor technologies will be considered unrealistically costly for many people (Combs et al., 2019). In fact, a study by Babbar & Lyons, (2017) forecast that the total per-vehicle costs for AV software and hardware components would be at around £3,000 by 2025 and would have decreased by 50% by 2035. Furthermore, Bansal et al., (2016) suggested that increases in the social acceptance of AVs and the reliability of SAVs will decrease the cost of usage. Hence, social acceptance of driverless cars is crucial in determining their price. In addition, the low cost of SAVs will increase shared mobility if they are shown to be reliable and accessible on-demand (Webb et al., 2019) While a survey conducted by Bansal et al., (2016) assessing public opinions of AVs in Austin, Texas demonstrated that fewer than 20% of respondents were willing to pay more for SAVs than existing car-sharing companies were charging for conventional vehicles, obstacles associated with high costs are likely to reduce with mass AV production.

A study by Wadud, (2017) used total cost of ownership to compare AVs and conventional vehicles (CVs) including private cars, taxis, and trucks in relation to cost, and suggested that commercial applications will be the highest beneficiaries from fully automated driving. However, the potential to adopt AVs in logistics depends not just upon the vehicles themselves but also on factors such as loading and unloading.

To conclude, all the above factors will play a significant role in determining end-users' acceptance of driverless technologies. However, previous studies suggest that the actual performance of AVs and how well they behave in reality on our roads will decide whether they eventually achieve social acceptance or not (Straub & Schaefer, 2018). A key factor in all of this will be the legislative frameworks adopted, and the legislative issues associated with AV adoption are discussed in the next section.

2.3.2.3. Legislation (including certification, regulation and ethical considerations)

The final group of barriers identified relate to the certification and regulation of AVs and the ethical issues associated with them. Developments in AV technologies mean driverless cars are rapidly becoming reality (Bichiou & Rakha, 2018), but legislation and national policies to regulate and control them has not reached the same stage (Kröger et al., 2018). In addition, the requirement for ethical reasoning has attracted significant interest in machine ethics, and it is crucial to learn the most effective ways to embed this into AVs (Narayanan, 2019). Figure 2-11 presents the factors that affect the legislation required to support the implementation of AVs and CAVs.

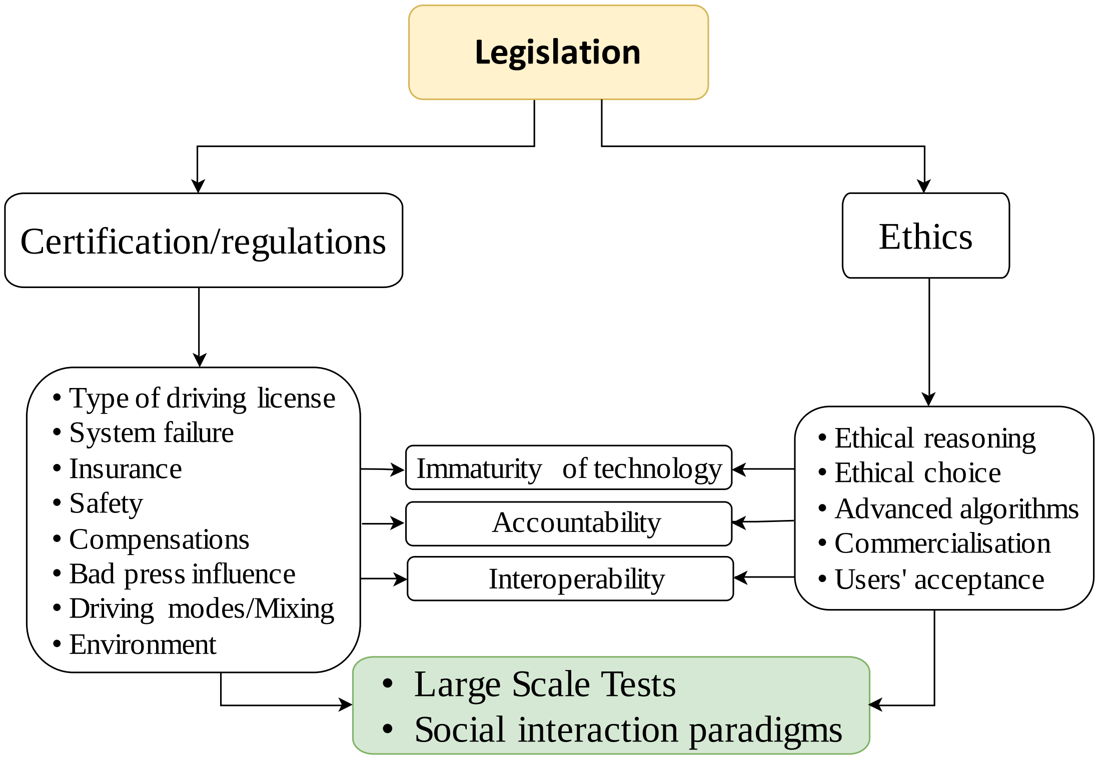


Figure 2-11. Factors that impact AV legislation (Bezai et al., 2021).

Legal issues are a prime concern in respect of the adoption of AVs since responsibilities must be evident in the case of a system failure (López-Lambas, 2018). Numerous questions arise, including who is accountable in case of an accident and whether vehicles or passengers will require some form of driving licence (Bichiou & Rakha, 2018). Liability is a paramount factor as it has a strong links with insurance, and legislation will be required to decide who should bear the costs of accidents; is it the victim, another actor, or shared (co-responsibility) (Schellekens, 2015). As a result, governments need to work with manufacturers and research organisations to embrace this new mobility and address the rising legislations issues to safeguard both users and pedestrians as far as possible (Noy et al., 2018; Ruggeri et al., 2018). Furthermore, policies regarding AVs should be developed neutrally and away from the "bad press" influence (Anania et al., 2018).

Ethical considerations are also crucial in determining AVs decision-making, and this must also reflect the relevant regulations. Not all crashes can be avoided; thus, AVs will have tough and complicated ethical choices to make. For instance, should AVs be running over pedestrians or acting to save them, even at the cost of its passengers? (Bonnefon et al., 2016). Without clear answers to these questions, the commercialisation of AVs and users' willingness to adopt them is likely to remain slow.

In order to develop legal frameworks that ensure personal safety, legislation facilitating large-scale testing of AVs is indispensable prior to their deployment on our roads. These tests will both advance the technological aspects of AVs and the applicable legislation (De Bruyne & Werbrouck, 2018). For instance, in September 2017, the US House of Representatives passed the Self-Drive Act to support AV testing. This includes several new regulatory tools to address issues such as requiring *"manufacturers to publicize their cybersecurity and data privacy plans"* (Congressional Research Service, 2018).

In terms of policies to support AV implementation, research by Chen et al., (2017) studied the possibility of using three different lanes policies for both AV and conventional driving modes. The first scenario provided a complete separation between both modes, with one lane dedicated only to AVs, and allows platooning, and the other for CVs only. In the second scenario, one lane was open for mixed traffic, both AVs platooning and CVs, with the other designated only for CVs. The final scenario reversed the second one, with one lane devoted exclusively for AVs whilst the other was open for mixed modes. The study concluded that the first scenario is the most likely one to be successful as it permits a smooth AVs transition. Another study by (Conceição et al., 2017) supported dedicated zones for AVs as an option for future policies in cases of mixed driving modes or to support their initial phase of penetration. Despite the limitations of their study model, the results demonstrated that this would help to decrease the travel time. These scenarios could be used to develop regulations while observing AV behaviour in testing phases and limiting the lanes for different driving modes if appropriate.

Previous research has highlighted several areas that require legislation, and the key policy priorities are safety, environmental impact, interoperability, liability, infrastructure and cost (Li et al., 2018). However, (Straub & Schaefer, 2018) stated that the outcomes of previous exploration regarding AV policy direction indicate that it will be a very difficult challenge to guarantee public safety with such rapid technological advances. They suggested that policies should not only be developed from the technological perspective but should also consider social interaction paradigms, such as those between users and AVs and other road users (Straub & Schaefer, 2018). In addition, in respect of developing a legislative tool for handling civil and AV liability, a commission by the European Parliament was urged to consider three elements; *"limitation to liability", system of liability determination* (is it strict liability or a risk management approach?), and *"obligatory insurance scheme and guarantee fund"* (Evas et al., 2018). The development of effective policies is expected to accelerate the development of AVs (S. Li et al., 2018); however, much more legislation will need to be created before a comprehensive legal framework can be put in place.

2.4. Conceptual Framework and Recommendations

2.4.1. Conceptual Framework

One of the key aims of this phase of the research was to create a framework which combined the obstacles identified in the literature review with the AV system architecture in order to establish the relationships between them. Figure 2-12 depicts the combination of the identified barriers and the AVs system architecture. Besides, it shows how each set of barriers affects the AV system as a whole (shown with coloured arrows). Overall, the analysis showed that these obstacles are intertwined but have slightly different impacts;

some directly affect individual phases, for example, computer software and hardware systems (no. 4) while others affect the overall system, e.g., legislation (no.3).

The aim in examining the obstacles to full AV adoption was to understand the internal and external factors contributing to their composition in order to identify suitable solutions, whether technical, social, legislative, or urban. For instance, an analysis of the barrier of users' acceptance and behaviour indicates that a significant proportion of people's unwillingness to use AVs is due to their distrust of automation. People still do not trust computers to drive them, even though they are believed to be much safer than human driving. This distrust can be linked to a number of factors, including a lack of public testing, cost, shareability concerns, and the role of the media. Consequently, a good understanding of these factors and their overlap enables identification of the most effective ways to address them and achieve full adoption of AVs.

The developed framework will be forming the basis of the final planning framework. The former will be expanded in the future phases including the output of the Phase II (survey experts) and Phase III (Users' behaviour).

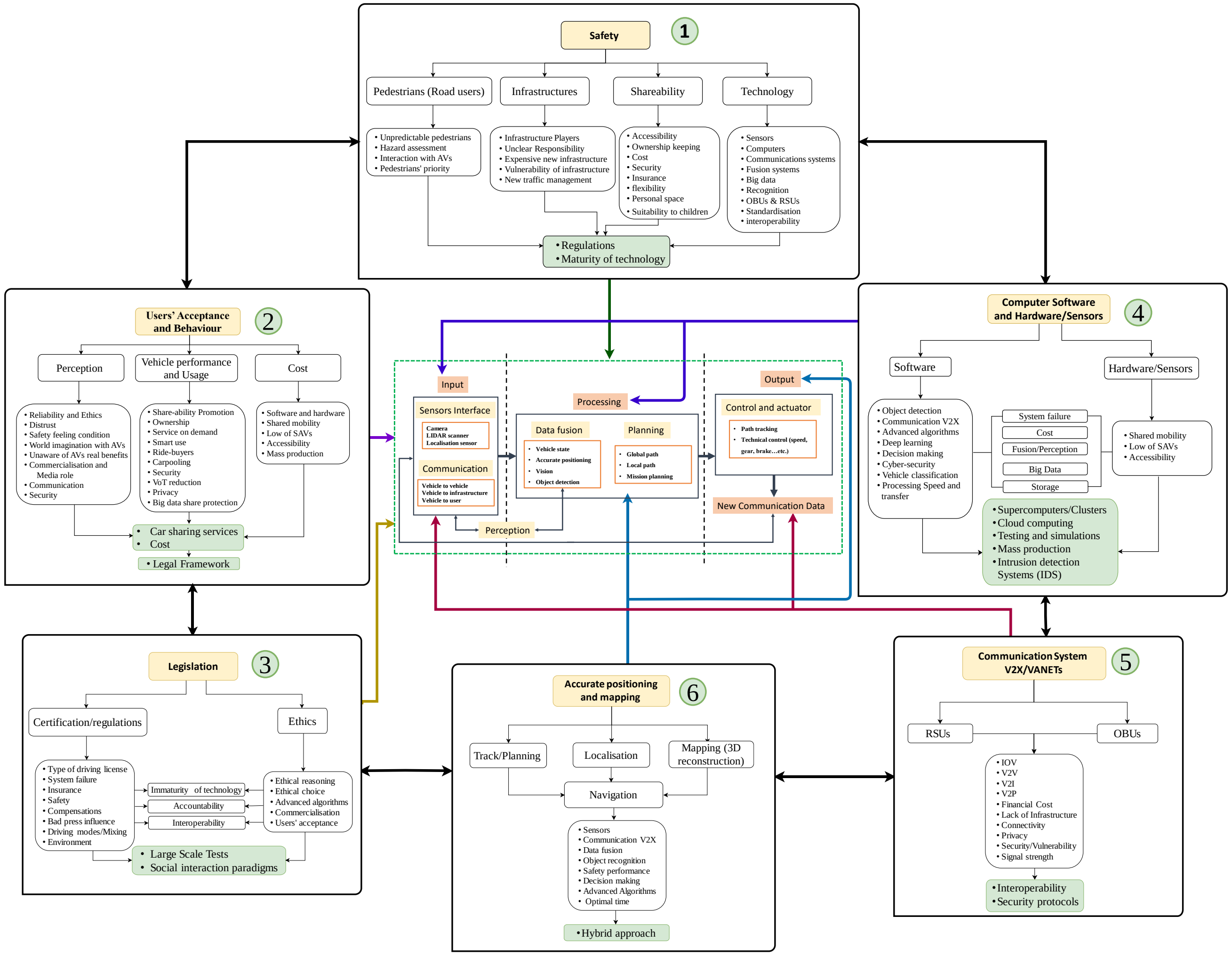


Figure 2-12. Framework combining all the barriers and their factors with the AV system architecture (Bezai et al., 2021)

2.4.2. Recommendations arising from the literature review

Based on the analysis of the barriers described above, this study recommends that action should be taken in a number of areas to support the full adoption of AVs. These are presented in Table 2-2. The recommendations below can be considered by decision-makers including stakeholders, politicians, planners, and future users.

Table 2-2. Recommendations to support the full adoption of AVs (Bezai et al., 2021)

Barriers		**Actions and recommendations**
User/Government perspectives	Users' acceptance and behaviour	• Maturity of technology including Supercomputers/cluster, cloud computing and IDSs • Simulations to study their impacts on different aspects such as energy and traffic • Regulations/ Legal framework that protect users • Car-sharing services and cost considerations • Enable large-scale tests of AVs in cities • Analysis of various social interaction paradigms • Use of Hybrid communication system approach • Develop Interoperability standards • Develop and embed Security protocols • Mass production
	Safety	
	Legislation	
Information and Communication Technologies (ICT)	Computer software and hardware	
	Communication systems	
	Accurate positioning and mapping	

2.5. the impact of Avs on urban planning and design

This study will focus on the urban impacts of autonomous vheicles from the point of view of Manual For Street 1 (MFS 1). The former offers guidance for practitioners who play a role in the planning process, design and new streets design approval, and amendments to existing ones (Great Britain. Department for Transport., 2007) . Its aim is to improve and increase quality through people-oriented streets. Therefore, the study will be revolving around Three main sections: Section A context and process, section B design principles and section C detailed design issues. Therefore the design of the second section III (proposition of the Journey see section: 4.4.2 Section II: AVs' impacts on urban areas, streets, and road design) in the survey questionnaire is based on the above.

2.6. Conclusion

This chapter has presented an overview of AV system architecture and provided a comprehensive systematic review of the barriers to full AV adoption in order to understand the factors involved and identify possible solutions. It began by listing the expected benefits of adopting AVs and highlighting some of the potential risks involved. It went on to describe the AV system architecture and the technical capabilities require to enable AVs to function effectively. It identified the key barriers to AV adoption in the literature, explored their associated factors, and considered potential solutions. These barriers were then combined with the system architecture to identify their impacts on individual phases and the system as a whole. This framework is developed throughout the study and forms the basis for the final framework presented in Chapter The chapter concluded by proposing further actions and recommendations to support the adoption of AVs based on the findings of the literature review. The next chapter describes the methodology which underpins this study.

Chapter 3: Methodology

Content

Chapter 3: Methodology

3.1 Introduction

"*Research means finding out about things*" (MacNaughton et al., 2010). Moreover, (Mertens, 1998) argues that the exact nature of research "*is influenced by the researcher(s)'s theoretical framework and by the importance that the researcher(s) places on distinguishing research from other activities".* Thus, the methodological choices a researcher makes are just as critical as the decisions made about how to put them into practice (Vogt, 2008; Yin, 2013). (John W Creswell, 2013) believes that what makes research successful, are three key concepts: research approaches, research designs and research methods. This chapter describes the methodology which underpins this study. It explains the research paradigms involved, justifies the approaches adopted, and establishes the time horizons. It goes to describe the research methodology, methods, and research design, providing justifications for the choices made. It then sets out the four-phase implementation process employed for the research and explains how the findings of each phase informed the subsequent phases. Details of the measures taken to ensure the reliability and validity of the research are also given. The chapter concludes by discussing the ethical considerations pertaining to this study.

3.2 Research Philosophies

It is essential to identify the philosophical assumptions behind any research, as these influence its plan, conduct, and, ultimately, the research findings. One of the main influences is the researcher's view of the relationship between knowledge and its development process (Slife & Williams, 1995). Understanding the assumptions that we have acquired about how the world works enables us to examine and challenge them, which in turn qualifies us to manage them differently. While researchers sometimes favour one research philosophy over another, each philosophy is appropriate for distinct things, and the choice depends to a large extent on the research questions ((M. Saunders et al., 2008). Practical considerations also help to determine the adopted philosophy. In short, the selection of the most appropriate research approach and the research methods involves various decisions, and these are informed by the philosophical assumptions and depend on the research problem (Creswell, 2013).

The research onion proposed by (M. N. K. Saunders, 2009) provides a useful way to understand the layers of approaches, strategies, methods, techniques and procedures involved in a study (See Figure 3-1). The philosophical stance or worldview is crucial in informing decisions about these elements and shaping the research style (Sapsford & Jupp, 2006). According to Jonson and Clark (2006, as cited in (M. Saunders et al., 2008), the essential issue is not whether the research is well informed philosophically, but how well researchers defend their choices and justify the methodological decisions they make.

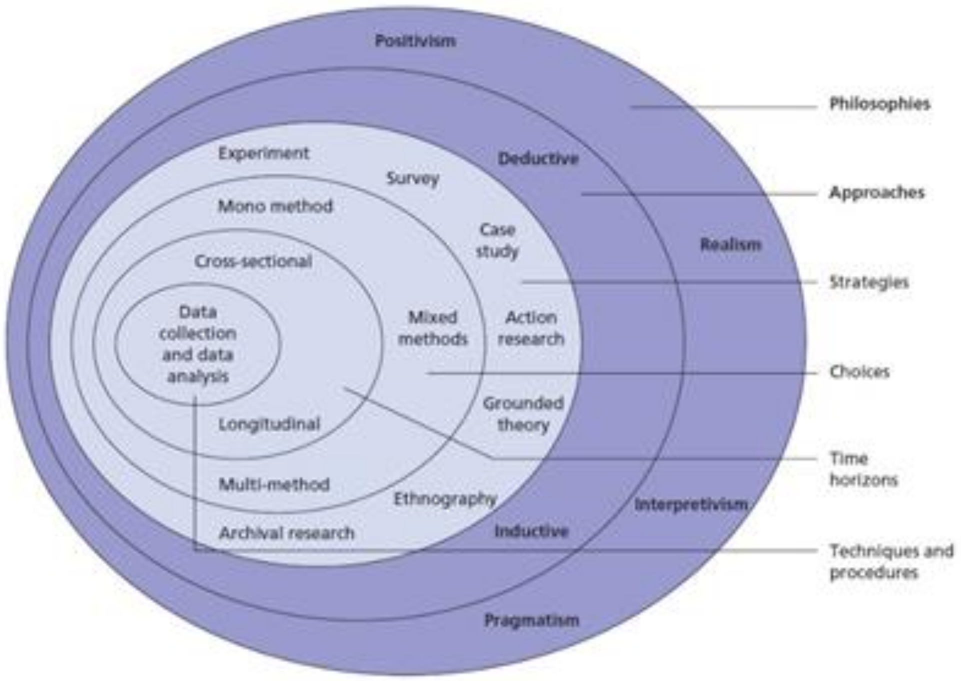


Figure 3-1. Research onion (M. Saunders et al., 2008).

Guba & Lincoln (1994, p.105) describe the research philosophy "*as the basic belief system or worldview that guides the investigator, not only in choices of the method but in ontologically and epistemologically fundamental ways*." As this indicates, there are two main methods of thinking around research philosophy: the ontological and the epistemological approaches. Both have differences that affect the research process; however, ontological and epistemological positions are connected because the epistemological position impacts the ontological position (Furlong & Marsh, 2010).

Ontology refers to the study of the nature of being and reality (Crotty, 1998). (Hitchcock, 1995) proposes that ontological assumptions are *"about the nature of reality and the nature of things"* The former raises questions about the assumptions that researchers have about the way the world works and what constitutes reality. Thus, researchers are seen as taking a position concerning their views of how things are and how they function (Scotland, 2012).

Epistemology refers to what comprises knowledge in a field of study. (Hitchcock, 1995) states that ontological assumptions *"give rise to epistemological assumptions; ways of researching and enquiring into the nature of reality and the nature of things."*

Consequently, both ontology and epistemology assumptions affect the methodical considerations involved in a study and thus the data collection and analysis involved (L. Cohen et al., 2017). This includes the research paradigm adopted, and the dominant paradigms are discussed in the next section in order to distinguish the most appropriate ones for this study.

3.3 Research Paradigms

A paradigm can be defined as *"a loose collection of logically related assumptions, concepts, or propositions that orient thinking and research"* (Bogdan & Biklen, 1998). (Mackenzie & Knipe, 2006) argue that the research process "*is more cyclical than linear*". Thus, the initial step is to define the research paradigm, otherwise, there will be no resulting decisions regarding methodology, methods and research design. The choice of the paradigm can also set down the goal, motivations and expectations of the proposed research.

Every paradigm is a particular accumulation of beliefs and convictions about knowledge and about our associations with it. Any paradigm has three components: an understanding of the nature of knowledge, a methodology, and criteria for validity (MacNaughton et al., 2010). Various theoretical paradigms have been debated in the literature, including Positivist/Post-Positivist, Constructivist, Critical/Transformative, Interpretivist, Emancipatory, Pragmatist and Deconstructivist (J W Creswell, 2013; Kivunja & Kuyini, 2017; Mackenzie & Knipe, 2006; Mertens, 1998; M. Saunders et al., 2008). Table 3-1 summarises the various assumptions associated with the four major paradigms: Post-positivism, Constructivism, Transformative, Pragmatic, adapted from Mertens, 2014). This includes epistemological and ontological assumptions, but also considers axiological assumptions, which deal with the nature of values and ethical behaviours in respect of research (Mertens, 2007).

Table 3-1. Illustration of the beliefs associated with the four significant paradigms (Mertens, 2014).

Basic Beliefs	***Post-positivism***	***Constructivism***	***Transformative***	***Pragmatic***
Axiology (nature of ethical behaviour)	*Respect privacy; informed consent; minimise harm (beneficence); justice/equal opportunity*	*Balanced representation of views; raise participants' awareness; community rapport*	*Respect for cultural norms; beneficence is defined in terms of the promotion of human rights and increase in social justice; reciprocity*	*Gain knowledge in pursuit of desired ends as influenced by the researcher's values and politics*
Ontology (nature of reality)	*One reality; knowable within a specified level of probability*	*Multiple, socially constructed realities*	*Rejects cultural relativism; recognises that various versions of reality are based on social positioning; conscious recognition of consequences of privileging versions of reality*	*Asserts that there is single reality and that all individuals have their own unique interpretation of reality*
Epistemology (nature of knowledge; relation between knower and would-be known)	*Objectivity is important; the researcher manipulates and observes in a dispassionate, objective manner*	*Interactive link between researcher and participants; values are made explicit; created findings*	*Interactive link between researcher and participants; knowledge is socially and historically situated; need to address issues of power and trust*	*Relationships in research are determined by what the researcher deems as appropriate to that particular study*

This research is concerned with developing a framework to assist planners, politicians, citizens, and stakeholders in decision-making relating to the adoption of AVs in our cities. This will be based on analysis of the existing literature, findings of a public survey, case study analysis, and the opinions of experts from different domains who are familiar with the concept of AVs and their potential impacts. This requires blended analytical methods and techniques. The following section explores the three major paradigms in more detail and identifies those which are relevant to this study.

3.3.1 Post-Positivism

The post-positivist movement claims that there is only one absolute reality that can be knowable within a set of laws and statements that govern the world. This is achieved objectively, where the researcher pursues the research with a dispassionate objectivity (Mertens, 2014). Hypothesis testing and empirical methods derived from natural science principles are to be used to achieve the reality. From this perspective, the post-positivist paradigm will be considered in this research since it is testing the hypothesis that "autonomous vehicles will impact city planning and users' behaviour". The procedure for testing the hypothesis relied mostly on identifying the impacts of AVs when the data was collected and analysed.

3.3.2 Constructivism

Constructivists, by contrast, believe that the world is versatile and assume that there are multiple social constructed realities (Mertens, 2014). Researchers within this paradigm seek to comprehend the world they live in by creating interactive links between themselves and the participants, taking into account the diversity of their backgrounds and experiences (John W Creswell, 2013). These multiple realities are not fixed and subject to change according to the participants' knowledge; therefore, constructivist research can embrace multiple and even opposing realities claimed by the participants, including the researcher himself (Guba & Lincoln, 1994). In light of the above respect, the constructivism paradigm aligns with several of the objectives of this study, including consultation with experts, such as urban planners, car manufacturers, and insurance companies, and the fourth objective to study and measure users' behaviour and opinions towards AVs. Hence, the adoption of this paradigm contributed towards building the final framework to support AV adoption.

3.3.3 Pragmatism

Pragmatism has various philosophy forms and "*arises out of actions, situations, and consequences rather than antecedent conditions*"(John W Creswell, 2013). In other words, pragmatists claim that rather than concentrating on methods and techniques, researcher(s) should focus on the research problem and try to use the available approaches and accessible methodologies to comprehend it. Pragmatists believe that the research problem is central and pragmatic research focuses on the 'what' and 'how' of the research problem (John W Creswell, 2013); thus all approaches can be applied to extract knowledge without being devoted to any particular paradigm, philosophy, or reality (Mackenzie & Knipe, 2006; Rossman & Wilson, 1985). The fundamental issue with this paradigm is that it neither debates the process behind choosing the methods nor the justification for using any method (Hall, 2013). Moreover, (Bellotti, 2014) stated that researchers adopting this paradigm face obstacles in analysing the results. Therefore, in light of the above reasons, pragmatism is not utilised in this study.

3.4 Research Approaches

Any research project involves the utilisation of theory; even if theory might not be apparent in the research design, it will be evident in the findings and conclusion. There are two main approaches to research; thus, researchers use either the deductive or the inductive approach, or, sometimes, a combination of both, even though they may not recognise it formally in their research ((Hyde, 2000). These approaches can be linked to different research philosophies; for instance, the deductive approach connects to positivism and the inductive to interpretivism, although this is not always the case (M. Saunders et al., 2008). The following section explains both approaches.

3.4.1 Deductive approach: Testing theory

(Robson, 2016) believes that deductive logic is used to test previous theories and concepts. In addition, (Dubois & Gadde, 2002) define deductive approaches as *"concerned with developing propositions from current theory and making them testable in the real world"*. This approach is also known as one which moves from the general to the specific. For instance, testing a pre-existing theory requires the collection of data on the determined variables according to the theory in a particular way; this is usually done through empirical observations (Collis & Hussey, 2014). Moreover, (Hyde, 2000) argues that deductive processes are usually embraced in quantitative enquiries that seek to test an established theory and apply it to specific circumstances. (Robson, 2016) states that the deductive approach can be divided into five successive stages:

1. Deducing a hypothesis
2. Expressing the hypothesis
3. Testing this operational hypothesis
4. Examining the specific outcome of the enquiry
5. Modifying the theory based on the findings, if necessary.

After these stages have been carried out, the whole cycle is repeated to check the updated hypothesis.

3.4.2 Inductive approach: Building theory

The other approach to research is induction. (Hyde, 2000) describes inductive reasoning as *"a theory building process, starting with observations of specific instances, and seeking to establish generalisations about the phenomenon under investigation"*, and (Robson, 2016) specifies that inductive logic is to be utilised where theory building and concepts are developed. Moreover, (M. Saunders et al., 2008) point out that research utilising inductive reasoning is more likely to be concerned with a context where small samples may be more suitable for consideration than larger samples. Hence, researchers in this approach tend to employ qualitative data through diverse data collection methods to provide various perspectives on the phenomena involved (Easterby-Smith, 2008). (John W Creswell, 2013) has identified several different stages of the inductive logic process in qualitative research, and these are illustrated in Figure 3-2.

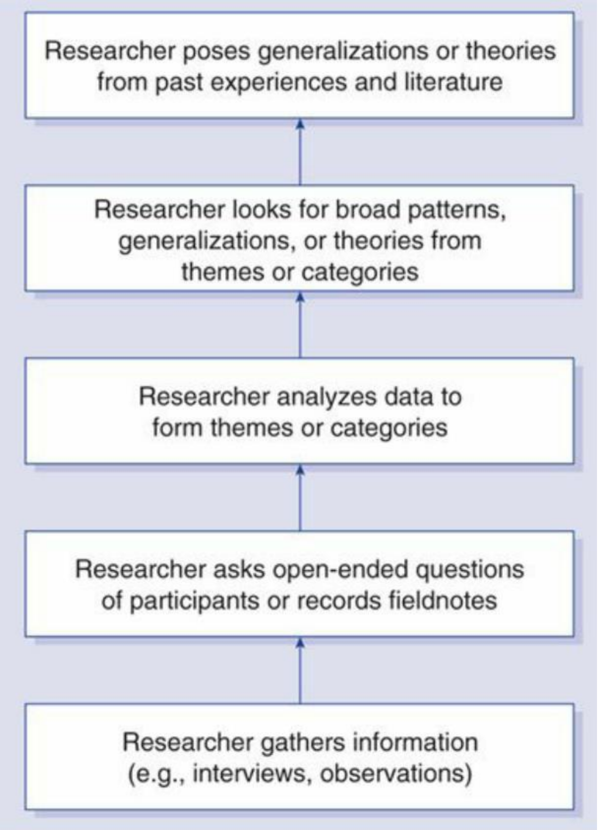


Figure 3-2. Stages involved in the inductive approach in qualitative research (John W Creswell, 2013).

3.4.3 Combining research approaches

While there are differences between these approaches, the idea that there are rigid distinctions between them is misleading, and combining deduction and induction within the same research work can be highly effective ((M. Saunders et al., 2008). (J W Creswell, 2013) recommends various practical criteria to identify which approach should be used, and perhaps the most significant of these are the research focus and its nature. For instance, for a topic on which there is an abundance of literature, a conceptual framework can be defined, and a hypothesis generated, deduction is more appropriate. Whereas, if the topic is new and there is a lack of literature, it might be more suitable to adopt an inductive approach, where data can be generated for analysis, and reflection on the resulting themes can suggest a theory. Therefore, to sum up both approaches, deductive is to test and inductive is to build.

Table 3-2 summarises the fundamental variances between the inductive and deductive approaches, and these can generally be understood in terms of whether the researcher(s) is looking at ‘why’ or ‘what’.

Questions about research approaches and the choices made are fundamental. (Mark Easterby-Smith, 2008) outlines three reasons for this:

- Firstly, being well-informed about the research approach enables the researcher(s) to make more informed decisions about the research design, the system by which information is gathered, and the procedures employed for analysis. Hence, it affects the general setup of the research work, including enquiries around what sort of evidence was collected, and from where, and how this evidence is translated to respond to the research question.

Table 3-2. Differences between deductive and inductive approaches (M. Saunders et al., 2008)

Deduction emphasises	***Induction emphasises***
• scientific principles *• moving from theory to data* *• the need to explain causal relationships between variables* *• the collection of quantitative data* *• the application of controls to ensure the validity of data* *• the operationalisation of concepts to ensure clarity of definition* *• a highly structured approach* *• researcher independence of what is being researched* *• the necessity to select samples of sufficient size in order to generalise conclusions*	*• gaining an understanding of the meanings humans attach to events* *• a close understanding of the research context* *• the collection of qualitative data* *• a more flexible structure to permit changes of research emphasis as the research progresses* *• a realisation that the researcher is part of the research process* *• less concern with the need to generalise*

- Secondly, it assists the researcher to think and reflect on potential research designs and choices to decide what will work best for the researcher(s). For instance, if the researcher is looking at why something is occurring rather than what is happening, it might be increasingly suitable to consider the inductive approach rather than deductive.

- Thirdly, learning about the research approaches empowers the researcher to adapt the research design to accommodate constraints. This can be useful, for example, where access to data is limited or there is insufficient information about the subject.

3.5 Time Horizons

According to (M. Saunders et al., 2008) when planning research, the question of whether the phenomena or the research problems is to be examined in a specific time frame (one snapshot) or on a number of occasions over a given time (combination of snapshots) needs to be asked. The single or short time snapshot is called cross-sectional, whereas a series of snapshots over a period of time is called longitudinal. Research time horizons are distinct and independent from the decisions about the techniques and methods used to address the research objectives, but the choice of snapshots is always dependent on the nature of the research questions and the time available. Given the circumstances of this study, the research undertaken is a cross-sectional study, and the reasons for this are as follows:

- *Time constraints*: This research aims to explore AVs' impacts and develop an adaptive urban planning framework to support their widespread adoption. The study is carefully structured around five objectives; however, due to the nature of doctoral study, the time set for this research is three years, so longitudinal study is not viable.
- *Nature of questions:* This research seeks to develop an urban planning framework, rooted in a literature review, to understand the current barriers to AV adoption and link them to the AV system architecture. It also explores users' behaviour and public perceptions of AVs using an online survey and consults experts in related sectors to validate and further develop the framework. Thus, it primarily captures people's opinions regarding AVs at a specific time (single snapshot), using the survey method, which is typically used in predominantly cross-sectional studies ((Mark Easterby-Smith, 2008).

To conclude, this study is cross-sectional based on the nature of research questions and the time constraints explained above.

3.6 Research Methodology

Amaratunga, Baldry, Sarshar, & Newton (2002) argue, that in the built environment, the utilisation of a single methodology regularly fails, so the use of mixed methods is recommended. In keeping with this view, the current study integrates both qualitative and quantitative research approaches in order to achieve its objectives. Both quantitative and qualitative methods can be employed with any research paradigm (Guba & Lincoln 1994), and utilised in tandem or sequence, making them complementary ((Sofaer, 1999). The purpose of using mixed methods is not to substitute any techniques but instead to draw on the qualities of both to limit the weaknesses in a single study ((Johnson & Onwuegbuzie, 2004). The main reason behind the choice of a mixed methodology is the philosophical position adopted in this research, which is a combination of post-positivism and constructivism. The former primarily embraces a quantitative research methodology whereas the latter mainly involves qualitative research. Table 3-3 summaries the research methodologies associated with the four major research paradigms.

Table 3-3. The main research methodologies associated with the major research paradigms (Mertens, 2014).

Basic Beliefs	***Post-positivism***	***Constructivism***	***Transformative***	***Pragmatic***
Methodology (approach to systematic inquiry)	*Quantitative (primarily); interventionist; decontextualised*	*Qualitative (primarily); hermeneutical; dialectical; contextual factors are described*	*Qualitative (dialogic), but quantitative and mixed methods can be used; contextual and historical factors are described, especially as they relate to oppression*	*Match methods to specific questions and purposes of research; mixed methods can be used as researcher works back and forth between various approaches.*

Table 3-4 shows the various forms of data collection associated with quantitative, qualitative and mixed methods research, as well as the statistical analysis methods and interpretations. It is believed that researchers should consider the whole range of data collections forms and classify them based on the degree of their nature, for instance, using closed-ended *vs* open-ended questions (John W Creswell, 2013).

Table 3-4. Research methodologies in regard to their data collection forms, analysis and interpretations (Creswell, 2013).

Quantitative Methods	***Mixed Methods***	***Qualitative Methods***
Pre-determined	Both pre-determined and emerging methods	Emerging methods
Instrument based questions	Both open- and closed-ended questions	Open-ended questions
Performance data, attitude data, observational data, and census data	Multiple forms of data drawing on all possibilities	Interview data, observation data, document data, and audio-visual data
Statistical analysis	Statistical and text analysis	Text and image analysis
Statistical interpretation	Across databases interpretation	Themes, patterns interpretation

Another reason for the use of a mixed methods approach is linked to the nature of the research questions. One of the main strength of the quantitative method is that it enables researchers to test and validate theories in respect of “How” questions. This often involves testing hypotheses that are developed before the data collection as well as generalising the research outcomes of data which are gathered by random sampling (Johnson & Onwuegbuzie, 2004). This aligns with this study’s hypothesis that “AVs will change users’ behaviour”. In addition, using quantitative methods to collect data, for example, by using a survey, can be administered and evaluated relatively quickly and responses tabulated within a short time (Choy, 2014). The numerical data acquired through this method simplify the comparison between different entities as well as permitting assurance of the degree of understanding or contradiction between respondents (Yauch & Steudel, 2003). Table 3-5 summarises the research paradigms and the methods adopted in this study, providing an explanation of their selection with reference to the research aims and questions.

Table 3-5. Research paradigms adopted with respect to the research questions (Author, 2019).

Basic Beliefs	***Post-positivism***	***Constructivism***
Considerations in this research	***Yes***	***Yes***
Why?	***The world is ambiguous, variable and multiple in its realities*** (O'Leary, 2017)***:*** **"It involves testing the hypothesis that autonomous vehicles will impact cities planning and users' behaviour."**	*"the world of human experience"* (John W Creswell, 2013) *Reality is socially constructed and based on the background and experiences of participants.* **To develop an urban design guide to support transportation infrastructure adapted to AVs.** *Through various subjective meaning.* **Test the hypothesis that AVs will change user behaviour.**
Methodology / Methods	**Quantitative methodology** • Structured questionnaires with quantitative data (Statistics) • Content analysis (Systematic review)	**Qualitative Methodology** • Semi-structured questionnaires with more qualitative data; open-ended question in the surveys) • Content Analysis and Document analysis.
Research questions	By which methods and strategies autonomous will cars be integrated into the city transportation infrastructure? What are the barriers and obstacles preventing AV adoption in current cities? How will the users' behaviour change?	What are the barriers and obstacles preventing AV adoption in current cities? What are the technologies and infrastructures needed to accommodate autonomous vehicles? Car specifications? What are the users' opinions and reactions to AVs? How will the users' behaviour change? Will AVs change the urban structure?

In addition, qualitative methodology is also considered appropriate for this study because it enables researchers to deal with complex phenomena, to describe them in rich detail, and identify the setting factors (Johnson & Onwuegbuzie, 2004). In addition, it seeks to comprehend and analyse a phenomenon from an individuals' perspective or outline it in an explanatory process (John W Creswell, 2013). It also offers the capability to examine values, beliefs, and different assumptions through broad, open-ended inquiries because participants can raise and point to other issues (Yauch & Steudel, 2003). This aligns with the first study objective, "To analyse barriers and obstacles that prevent the adoption of AVs in current cities". This involved working closely with different experts to identify and validate AV barriers and consider the potential impacts of AVs. Data was also collected from participants to investigate their willingness to adopt this technology.

Qualitative methods aid in defining the research focus and questions, which contributes to theory building inductively as it guides questions rather than accurate hypotheses. In addition, using qualitative methodology produces theories that clarify "how" and particularly "why" entities behave as they do (Szajnfarber & Gralla, 2017). Moreover, (Neuendorf, 2016) states that, most of the time, research that may be portrayed as qualitative is actually quantitative and what makes it qualitative is the phenomenon being studied itself.

In summary, although some of the research questions in this study are quite qualitative in their nature, both quantitative and qualitative methods are used. For instance, to establish and validate a framework to overcome AV barriers which answers the research question "What are the barriers and obstacles preventing AV adoption in current cities?", content analysis, systematic review, and semi-structured surveys were employed, a combination of qualitative and quantitative methods, although the research question is qualitative in nature.

3.7 Research Methods

(M. Saunders et al., 2008) advise that it is good practice to evaluate all possible data collection methods before selecting the most appropriate method. Table 3-6 summarises the common research methods utilised under the positivist/post-positivist and constructivist paradigms and the data collection tools used in quantitative and qualitative methodologies. It also sets out the data collection tools chosen for use in this study. The following section explains the motivations behind their selection.

Table 3-6. Research methodologies suited to the paradigms adopted in this study (compiled from *(Kivunja & Kuyini, 2017; Mackenzie & Knipe, 2006; Merriam & Tisdell, 2015; Zikmund, 2013)*.

Methodology/tools	**Positivist/ Post-positivist Quantitative**	**Constructivist/ Interpretivist Qualitative**
Research methodology used in each paradigm	• Experimental methodology • Quasi-experimental • Correlational • Causal comparative • Randomised control trials • Survey research	• Naturalist • Narrative inquiry • Case study • Grounded theory • Phenomenology • Hermeneutics • Ethnography • Phenomenography • Action research
Data collection tools used in each paradigm/Methodology	• Experiments • Quasi-experiments • Content analysis • Systematic review • Surveys • Tests • Scales	• Interviews • Observations • Document reviews • Visual/Audio data analysis • Focus group • Collages • Conversations • Thematic Apperception/Cartoon tests
Chosen research methods in the undertaken research	• Closed-end questions • Survey • Content analysis	• Open-ended questions survey • Content analysis •

(J W Creswell, 2013) states that a survey provides a *"numeric description of trends, attitudes, or opinions of a population by studying a sample of that population. From sample results, the researcher generalizes or draws inferences to the population".* First, the survey technique was employed, and the main reason is related to the nature of the research question and the research case study chosen for this study. The city of Nottingham was selected as a case study to examine users' acceptance and behaviour when adopting AVs in order to answer the research question "How/will the users' behaviour change?". However, there was no secondary data available to consider in relation to forecasting Nottingham residents' attitudes regarding AVs.

3.7.1 Content analysis

Content analysis has been defined as *"the systematic, objective, quantitative analysis of message characteristics"* ((Neuendorf, 2016). Additionally, (Stemler, 2001) argues that content analysis is also beneficial for exploring trends and patterns in documents. As a result, content analysis was also chosen as a research method for this study. The main reason for this is due to the nature of the first research question: “What are the barriers and obstacles preventing the adoption of AVs in current cities?” Answering this question necessitated a systematic review of the literature, and content analysis was employed to identify barriers based on the trends and patterns that emerged from documents such as journal articles, conference papers, and web-pages.

Content analysis is a good tool to evaluate secondary data and synthesise the findings of primary research, and it has quickly turned into a foundation of evidence-based research (Dixon-Woods et al., 2006). In addition, advances in computer and digital tools have made it easier and quicker. For instance, in this research NVivo 12 Pro was used to analyse previous studies using mixed methods as it can analyse but just texts but also images, videos, audio, social media, surveys, and interviews (QSR international, 2019). For the above reasons, content analysis was found to be suitable to address Objectives 1 and 2.

3.7.2 Survey

The survey has several advantages, such as the economy of the design as well as the fact that it is a quick technique to use as it provides rapid data collection (Fowler, 2009). It also offers real-time error checking, making the data collection process more accurate (Solomon, 2001). Fowler (2009) states that surveys can take different forms: postal, online, phone, personal interviews, and group administration; however, in this study, the online survey was selected for reasons of cost, availability, and convenience. For instance, participants were able to take part in the survey whenever it was convenient for them. Distribution via emails and social media links was easy and quick and enabled the survey to reach a large number of participants. Thus, based on the reasons mentioned above, the survey technique was considered adequate to address Objectives 1, 2 and 4.

3.8 Research Design

According to (Sarantakos, 2012), whether research adopts quantitative or qualitative methods, the overall models (designs) utilised share a similar general structure with five basic criteria: (1) the study is carried out following certain steps which work as a guide; (2) the steps are well defined and are followed in this in this order: research topic choice, methodological construction, sampling, data gathering, data analysis and reporting; (3) moving from one step to another differs from quantitative to qualitative research; (4) the research design is set up prior to beginning the research; and (5) the order degree of moving from step to step depends on the paradigms involved. (Sarantakos, 2012) adds that any research has two leading stages: the first is the planning stage and the second is the implementation stage. The first stage is where the research design is elaborated, and it explains in detail how the research will be conducted. The research design of this research is presented in Figure 3-4 at the end of this section.

A study by (Bryman, 2006) examined 200 social articles which employed a mixed-methods research methodology with a focus on the research design. (Bryman, 2006) concluded that there are five main reasons behind the study design selection. Table 3-7 presents these reasons and explains how they were applied in relation to this study.

Table 3-7. The five main reasons behind research design choices and their application in the current study (Bryman, 2006).

Reason	How and why the method was adopted in the research
Triangulation	Uses multiple data sources and collection tools to reinforce research findings (See Figure 3-4)
Complementarity	Uses several research strategies to complement and enhance different aspects of the enquiry and cover the missing sides. For instance, a semi-structured survey is conducted where quantitative and qualitative data is required to fill gaps.

Development	Uses the findings of one method to inform and develop another method where further actions can be taken, including sampling and implementation. For instance, results from the content analysis led to identifying themes and designing surveys 1 & 2.
Initiation	Seeks to identify contradictions to form new perspectives where outcomes and questions can be recast from different method. This reason was not adopted in this research.
Expansion	Uses various methods to extend the breadth of the research enquiry. Different methods were used in this research to answer different enquiry components (document analysis, content analysis, and surveys 1 & 2) to develop an urban model to assist planners, politicians, citizens and other stakeholders in their planning decision-making when adopting AVs.

Furthermore, (John W Creswell & Clark, 2007) state that there are four major research designs when adopting a mixed-methods approach: the exploratory design, the triangulation design, the embedded design, and the explanatory design. However, they argue that the most common design is the triangulation design because it enables researchers to acquire various and complementary data on the same subject for a better comprehension of the research enquiry. Moreover, employing the triangulation design is complementary; for instance, the strengths of the quantitative methods will cover the weaknesses of the qualitative methods and vice versa ((John W Creswell & Clark, 2007).

The four variants of triangulation design are: *"the convergence model, the data transformation model, the validating quantitative data model, and the multilevel model"* (John W Creswell & Clark, 2007). Figure 3-3 shows the multilevel triangulation process whereby both quantitative and qualitative methods are employed to address the different levels of the research problem and the results inform the overall interpretation.

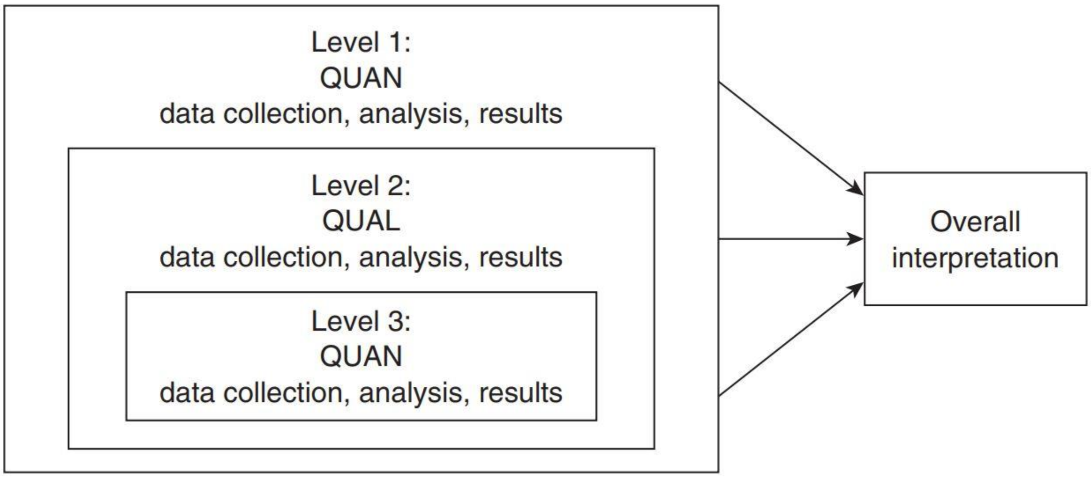


Figure 3-3. Triangulation design: Multilevel model (Tashakkori & Teddlie, 2010).

(J W Creswell, 2013) highlights two triangulation methods: (1) employing methods at the same time (simultaneous), and (2) utilising the results of one method to plan the following method (sequential). Thus, another advantage of using triangulation design is the flexibility of using methods independently and/or dependently.

After careful consideration of the research objectives and the methodological choices already made, the triangulation design was adopted in this research, more precisely, the multilevel, mixed methods model of triangulation design presented in Figure 3-3. As the current research employs complementary objectives to address different research questions type, the multilevel model was seen as adequate to achieve the overall aim of this study. For instance, to address Objectives 1, 2 and 3, methods were carried simultaneously and sequentially. By contrast, Objectives 4 & 5 harnessed the results of the former objectives (sequentially), and the findings from all levels were merged to inform the overall interpretation. The following section explains in detail how the selected quantitative and qualitative methods were implemented in the current research and whether they were used simultaneously or sequentially. This is also illustrated in Figure 3-4.

1. Content analysis and document analysis were used simultaneously to identify AV barriers and vehicle specifications (AVs system architecture). This informed the creation of a preliminary framework assembling all the potential barriers and their relationship to the AVs system architecture. This addressed Objectives 1, 2 and part of Objective 3.

2. The outcome of the content analysis and document analysis informed the design of a survey to collect further data. This targeted experts in different disciplines, such as planners, of city council members, IT experts, vehicle manufacturers, and insurance companies, in order to identify the impact of AVs in a range of areas. These experts were later asked to evaluate the final planning framework in order to validate its content. In addition, the survey proposed an AV journey for the experts to examine the possible impacts of full AV adoption, with reference to design principles and detailed design issues (according to MFS 1 or 2). This addressed Objective 1 and part of Objective 3.

3. The results obtained from the content analysis and the first survey contributed to the design of a second survey that aimed to study users' acceptance and behaviour when adopting AVs.

4. Finally, the findings from all the above methods informed the design of the last method which was a focus group. This was used to address the fifth objective which consists of establishing a final urban model and recommendations to assist planners, citizens, politicians, and stakeholders in their planning decision-making in respect of AVs.

Besides, Table 3-8 illustrates the interrelation between the aim, objectives, research questions, and the methods and techniques adopted in this research.

To conclude, based on the research philosophies, paradigms, methods and the research design, it was considered most practical to divide the research implementation into several phases. As Figure 3-4 illustrates, four main phases were established in order to address all research objectives. These are described in detail in the following sections.

Table 3-8. Interrelation between the aim, objectives, questions, and methods and techniques adopted in this research (Author, 2019).

Aim	**Objectives**	**Research question**	**Research Methods/techniques**	
To explore the potential of autonomous cars and develop a more adapted urban design model to assist planners, citizens, politicians, and stakeholders in their planning decision-making.	Obj. 1: To analyse the barriers and obstacles that hinder the adoption of AVs in today's cities.	What are the barriers and obstacles preventing adoption of AVs in current cities?	• Content Analysis using NVIVO • Survey designated to experts (semi-structured) **Limitations**: ▪ Involve some level of subjectivity ▪ Time consuming (Luo, 2022) • Survey designated to experts (semi-structured) **Limitations**: ▪ Collect data at single poin in time ▪ Lack of depth (Decarlo, 2022)	*Quantitative and Qualitative methodology*
	Obj. 2: To analyse vehicle specifications and their impact on the urban transportation infrastructure	What are the technologies and infrastructures which need to be evolved to accommodate AVs? Car specifications?	• Document analysis • Case study analysis	

	Obj. 3: To determine the possible impacts of AVs on city planning and transportation infrastructure	How will autonomous cars be integrated into the city's transportation infrastructure?	• Content analysis from Objective 1 • Journey analysis by the experts	*Qualitative methodology*
	Obj. 4: To analyse and measure users' behaviour	How will users' behaviour change?	• Questionnaire (structured)	*Quantitative methodology*
	Obj. 5: To develop an urban design guide to help transportation infrastructure adapt to AVs	Will AVs change the city's urban structure?	• Document analysis **Limitations:** Requires considerable investigation skills	*Qualitative methodology*

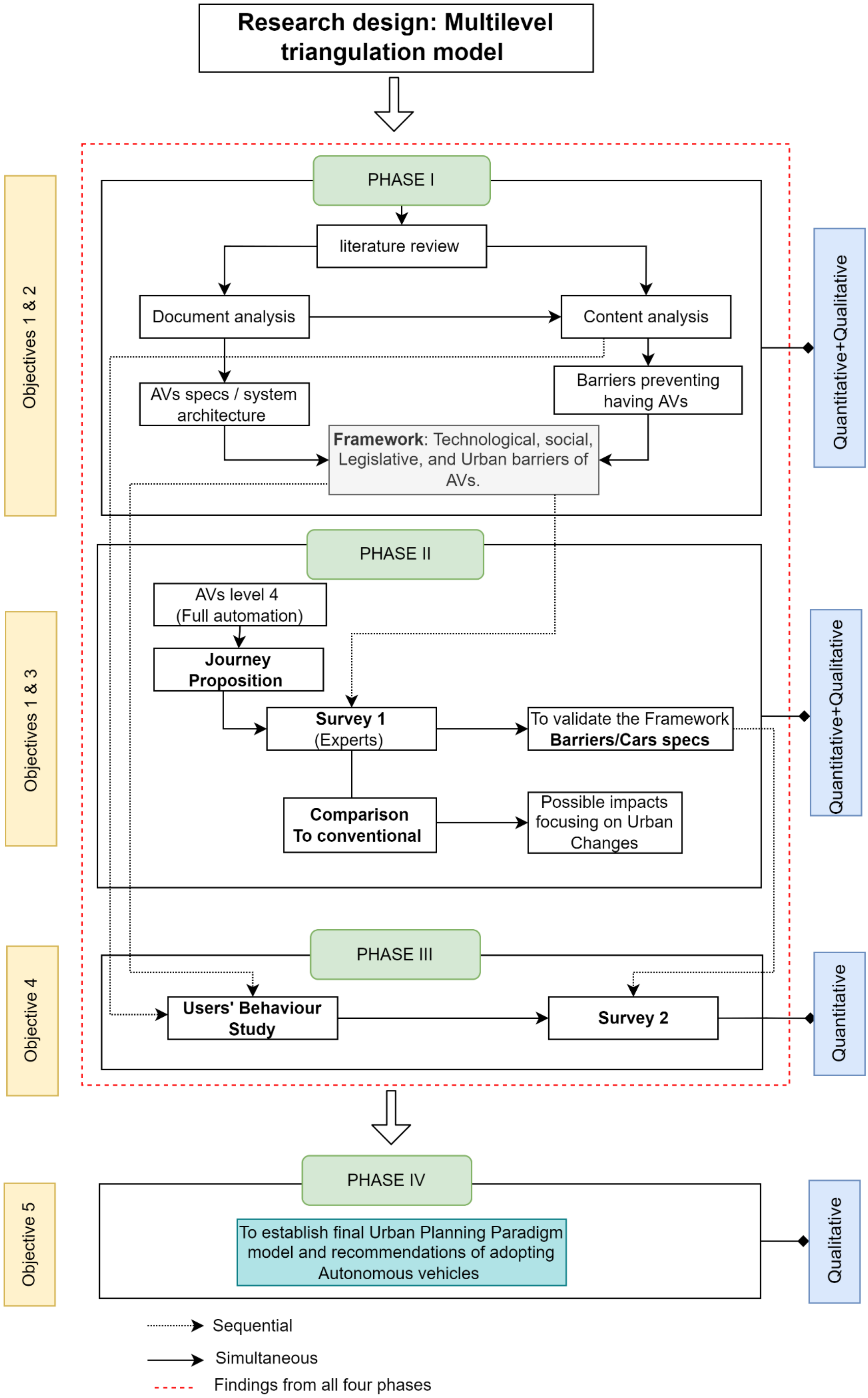


Figure 3-4. Research design, mixed methods and the triangulation forms (Author, 2019)

3.9 Practical Implementation

Following the multilevel model triangulation research design, the implementation of the study was carefully organised around four distinct phases. Each phase is described below.

3.9.1 Phase I

Figure 3-5 provides an overview of this phase, showing the relationships between the methods used and the ways in which the findings of this stage informed other phases.

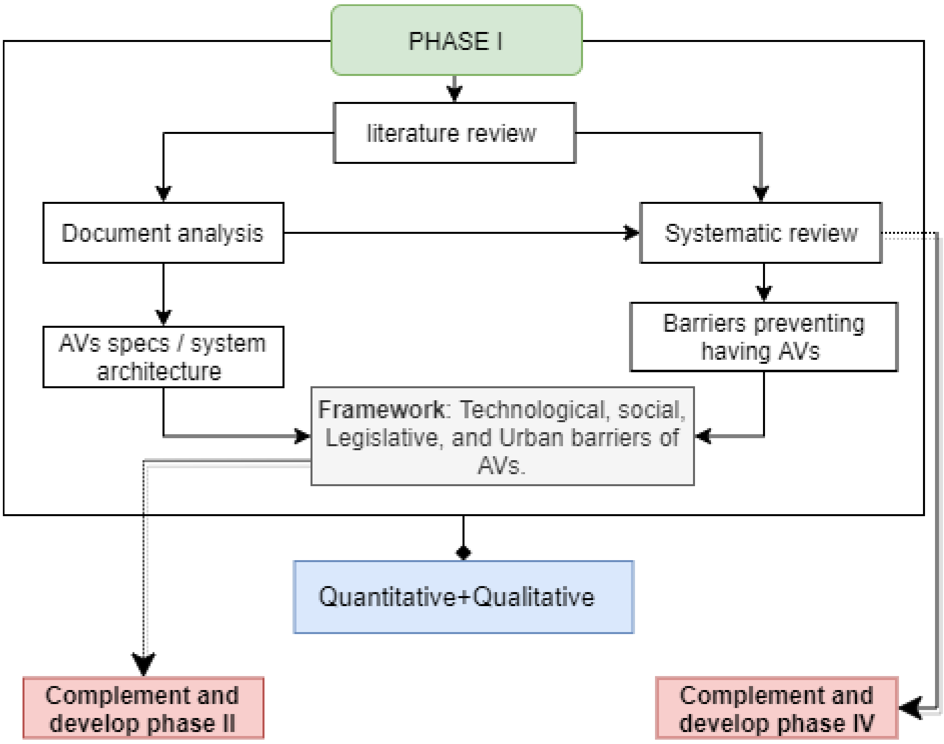


Figure 3-5. First phase: Literature review using systematic review and document analysis (Author, 2019).

3.9.1.1 Goal and purpose

The main intention of this stage was to address Objectives 1 and 2 of the research; to identify and analyse the barriers and obstacles that prevent adoption of AVs in current cities and to analyse vehicle specifications and their impacts on the urban transportation infrastructure. This phase also permitted the identification of further the gaps in the literature. The main output in this phase was the development of a preliminary framework which links the technological, social, legislative, and urban barriers identified to the AV system architecture.

The outcomes of this phase contributed to the design of Phases II and IV and parts of Phase III. For instance, the themes of both surveys were extracted from the content and document analysis conducted in this phase.

3.9.1.2 Content and document analysis

***Methodology*: Quantitative and qualitative**

***Methods*: Content analysis and document analysis**

***Tool*: NVivo 12 PRO**

Content analysis and document analysis was employed to critically review state-of-the-art literature about AVs, with more than 82% of selected papers published since 2017. The focus was on papers that refer to issues and obstacles to AV adoption. Various types of publications were examined, such as journal articles, books, book sections, reports, web-pages and conference proceedings; however, approximately 70% of the sources were journal articles. This systematic review followed a technique of classification employing the taxonomy approach which is considered to be more empirical (Bailey, 1994). Figure 3-6 illustrates the proportion of material published each year (from 2012 to 2019) and the different types.

A mixed-methods research methodology composed of four stages was adopted for the content analysis in order to address Objective 1. Figure 3-7 provides a content analysis methodology flowchart, showing how the stages were performed and whether they were quantitative or qualitative. Each stage is described in more detail below.

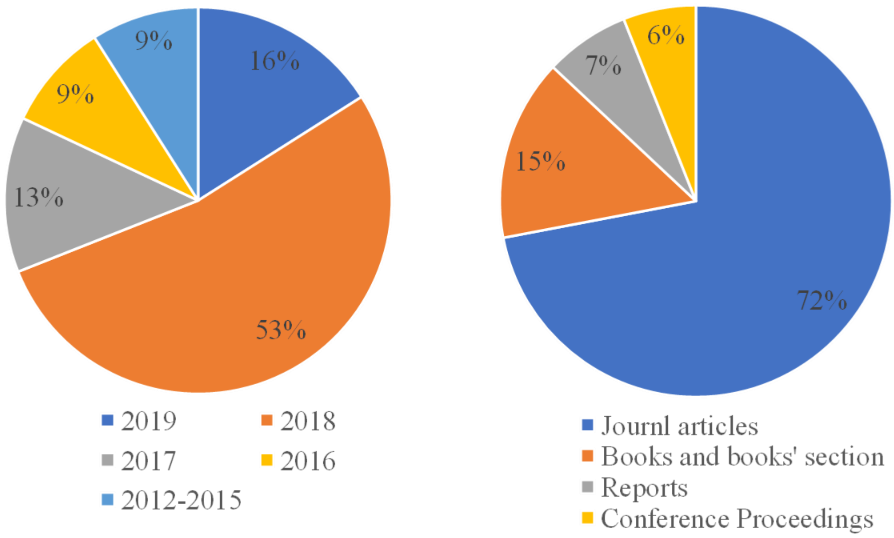


Figure 3-6. Publication dates and types of sources analysed (Author, 2019).

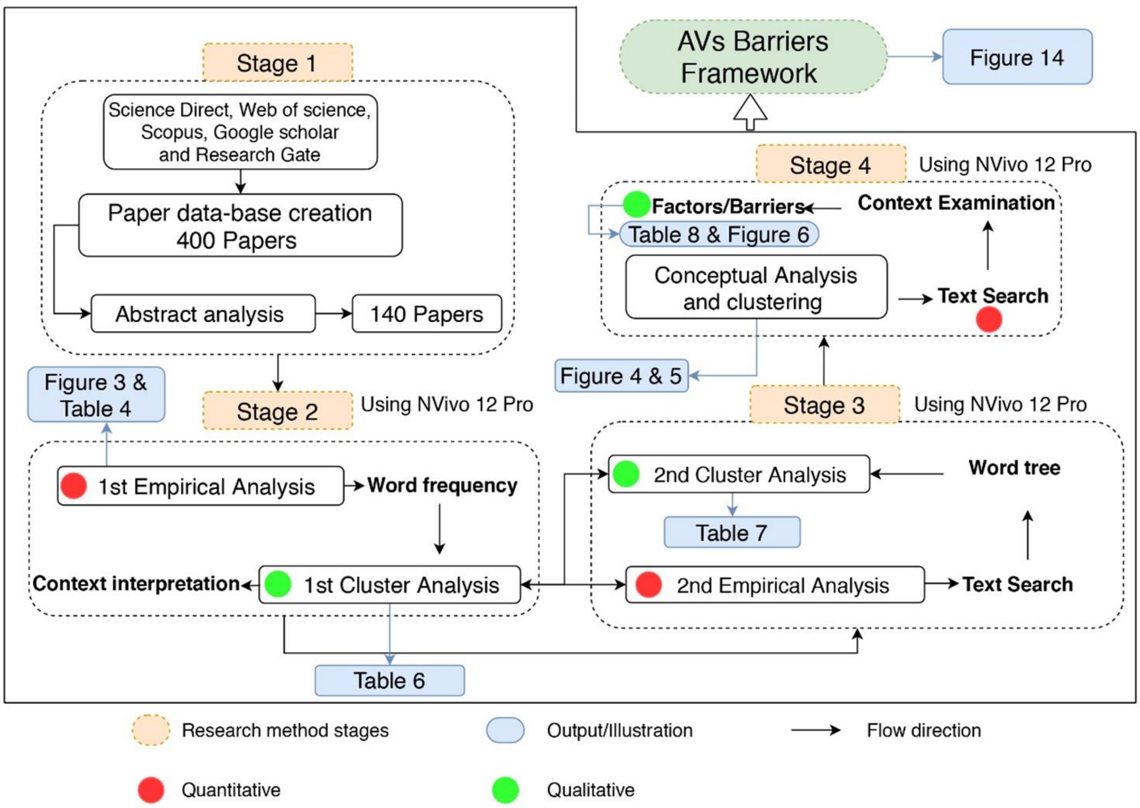


Figure 3-7. The content analysis flowchart for this study (Bezai et al., 2021).

The first stage began by building a database of papers. Firstly, a search was conducted by including words related to AVs, such as ‘driverless’ and ‘self-driving vehicles’ and searching leading online databases, i.e., ScienceDirect, Web of Science, Scopus, Google Scholar and

ResearchGate. Secondly, an in-depth analysis of the abstracts and relatedness of 400 papers was carried out, which led to the selection of 140 sources.

The second stage consisted of two phases; (1) empirical analysis was conducted using NVivo 12 Pro software by employing the word frequency function on the selected sources and looking for words of a minimum length of four letters. The grouping criteria to measure the similarity level was set to exact matches. Figure 3-8 and Table 3-9 illustrate the most frequently occurring words and their weighted percentage (obtained from the second stage). Then, (2) cluster analysis of the generated concepts from the word frequency was conducted (See Table 3-9). This was done by analysing the words in context to cluster them in groups based on their possible interpretation. The analysis indicated that the concepts which emerged could be classified into four groups: technical, social, legislative and urban. The word "data", for example, was linked to technical, social and legislative. Table 3-10 illustrates how the context of "data" was associated with different interpretations.

Figure 3-8. Word cloud of the 40 most frequently occurring words e (Bezai et al., 2021)

Table 3-9. Word frequency and their weighted percentage (Bezai et al., 2021)

Word	Count	Weighted Percentage (%)
data	3871	0.44
time	3865	0.44
control	3116	0.35
technology	2736	0.31
safety	2564	0.29
information	2389	0.27
public	1818	0.21
liability	1765	0.20
traffic	1717	0.19
travel	1709	0.19
network	1628	0.18
mobility	1604	0.18
future	1448	0.16
human	1424	0.16
urban	1402	0.16
speed	1267	0.14
lane	1258	0.14
communication	1243	0.14
planning	1234	0.14
cost	1124	0.13
services	1101	0.12
connected	1099	0.12
policy	1096	0.12
intelligent	1062	0.12
risk	1043	0.12
demand	1040	0.12
market	1039	0.12
software	1007	0.11
environment	984	0.11
users	950	0.11
sharing	922	0.10
people	887	0.10
simulation	825	0.09
detection	817	0.09
privacy	815	0.09
energy	813	0.09
test	808	0.09
insurance	794	0.09
social	794	0.09
infrastructure	740	0.08

Table 3-10. Example of context analysis of the word 'data' and its associations (Bezai et al., 2021)

Context	**Source**	**Interpretation**
*"**Data** <u>Fusion</u> (DF) presents a key point in road safety applications"*	(Armingol et al., 2018, p. 24)	Technical
*"<u>willingness of end-users</u> to give consent to broadcast **data** is not a barrier, in particular if the data is to be used to enhance road safety"*	(Alfonso et al., 2018, p. 136)	Social
*"It is essential that any **data** <u>gathered</u> from CAV are used in accordance with data <u>protection law</u>"*	(House of Lords Science and Technology Committee, 2017, p. 8)	Legislative

Following the same method, the third stage also involved two phases: (1) an empirical analysis, and (2) utilising the NVivo 12 Pro function "Text Search" instead of "Word Frequency" on the four clusters (technical, social, urban and legislative). The first phase was carried out on the papers in the database created in Stage 1. The second phase involved analysing the four clusters using the word tree function in NVivo. Figure 3-9 illustrates 'legislation' as an example of a word tree function output.

Table 3-11 summarises the four clusters generated from the analysis of all the words listed in Table 3-9, where the symbol (X) indicates the association of the concept with the cluster. Table summarises the 2nd cluster analysis, where the outcomes of the second phase were divided into two groups: ICT and User/Government perspectives. This part of the study investigation focused on identifying the issues and obstacles that AVs are facing. The outcome of the three stages revealed that the full adoption of AVs depends on various key barriers being overcome. These are listed at the bottom of Table 3-12.

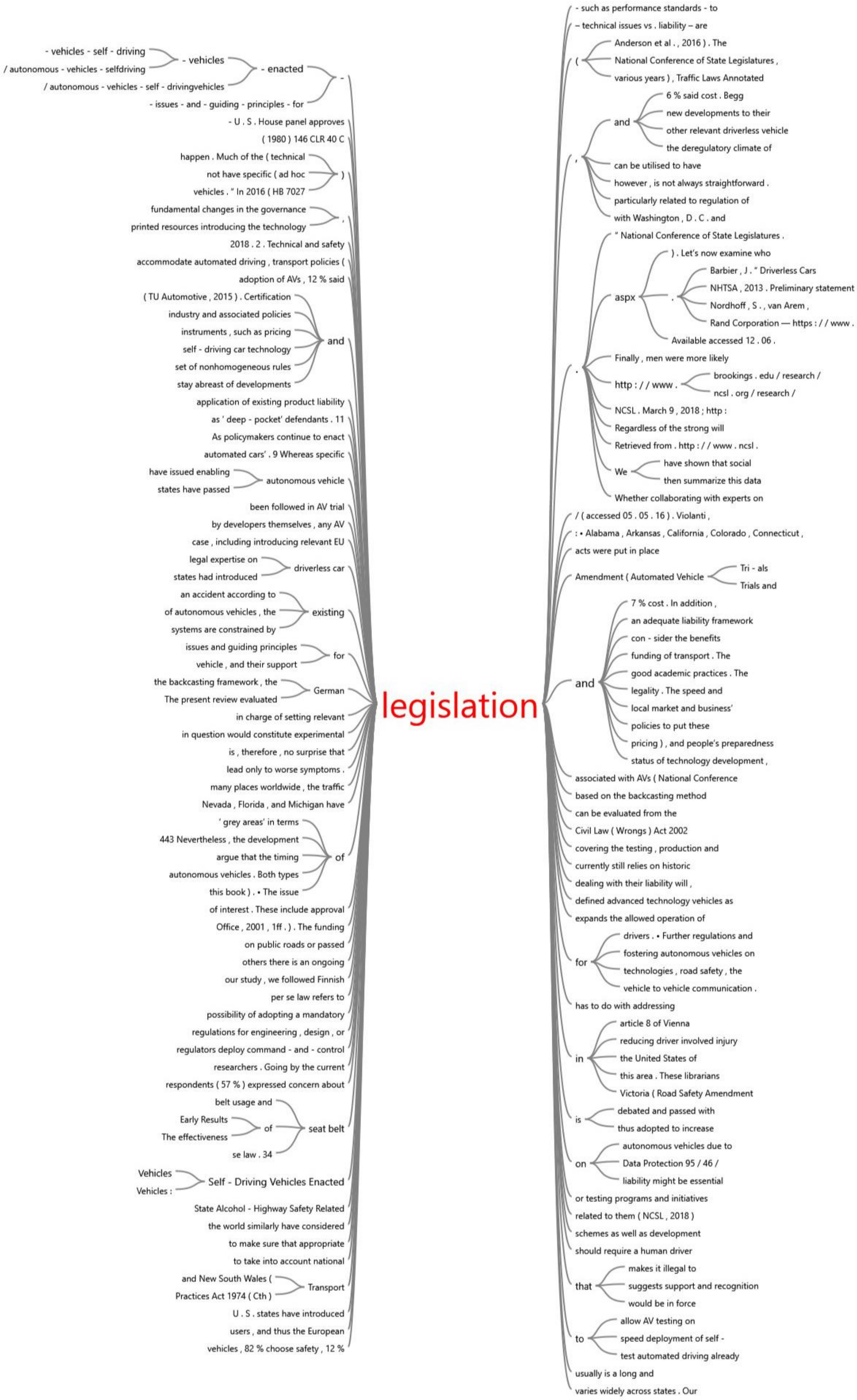


Figure 3-9. Example of a word tree function for 'Legislation' (Author 2019).

Table 3-11. Concept clustering based on the words in their context (Bezai et al., 2021)

Word	Technical	Social	Urban	Legislative
data	x	X		X
time	X	X	X	
control	X	X		
technology	X	X	X	X
safety	X	X	X	X
information	X	X	X	X
public		X		X
liability	X	X		X
traffic	X	X	X	X
travel	X	X	X	X
network	X		X	X
mobility	X	X	X	X
future	X	X	X	X
human	X	X	X	X
urban			X	
speed	X	X	X	
lane			X	X
communication	X	X	X	X
planning		X	X	X
cost	X			X
services	X			
connected	X			X
policy		X		X
intelligent	X		X	
risk	X	X		X
demand		X		X
market	X	X	X	X
software	X			
environment	X	X	X	X
users		X		X
sharing	X	X	X	X
people	X			X
simulation	X			
detection	X			X
privacy	X	X	X	X
energy	X	X	X	X
test	X	X	X	X
insurance	X	X		X
social	X	X	X	X
infrastructure	X	X	X	X

Table 3-12. 2nd clustering based on the word tree of the 1st clustering analysis (Bezai et al., 2021).

Technical	Social

89 sources 353 count	91 sources 908 count
Technology Vehicular Communication/Sensors Computer/network/simulation/Ad Hocs/VANETs Real-time control Human-Machine Interface Navigation/ Mapping/Positioning Safety Travel behaviour/forecasting/attitude Path reconstruction Certification/legal/policy/Law/liability/ Regulations// Standardizations Traffic management/performance Shareability Platooning Testing	Safety Sustainability Behaviour/Control/Change/Forecasting/Psychological perspectives/ perception Identity/Adoption/acceptance/Ownership Sharing systems/Norms/Participation/Trips Information/Data/Accessibility Ad Hocs /Networks/ Smartphones/technology/Navigation Benefits/Opportunities/ Failure/Attacks/Emergency Infrastructural factors/smart cities Economy/finance/cost/commercial Media/Politics/Government/Educational/Research Events/needs/ Employment/Independence/disability IoT/IoV/SIoV Activities/Recreations
Legislative 33 sources 112 count	**Urban** 109 sources 1306 count
Safety Pedestrian/Change Technical/ V2X communication/ Technology maturity Civil law Law Backcasting approach Liability/Standards/Guiding-principles/Policies/ Regulations/Funding transport Insurance Research/collaboration Market and businesses Experiments/testing Pricing/cost Data Protection	Safety/Regulation/Policies Planning/Infrastructure/Centre parking Cities/Rural/Regional/suburban/agglomerations/ sprawl/Dispersion/building/Trips/Commute/Mobility-models/Sharing/travel-time/distance-travelled/ Cybernetic-Public-transport/Taxi/ Urban design/space morphology/ Urban mobility/Traffic Management/ Surface/roads/Street/crosswalk/intersection/ Highway/Expressway/roundabouts/Pathways/Nodes Environment/Tourism/Population/Geography/ Land/Location/landscape Accessibility/maintenance/charging stations/ Technology/Vehicular communication/ Network/Positioning/Simulation/GPS/smart servers/ Platooning Users/Privacy/Community/Sensors Services/Demand/density/congestion/footprint Testing
• Safety • Users' acceptance and behaviour • Legislation	• Accurate positioning and mapping • Computer software and hardware • Communication systems

The final stage of Phase I was a conceptual analysis of the barriers which were identified in the previous three stages, with an examination goal that was set to explicit terms (See Figure

3-9). This stage was also done using NVivo 12 Pro, utilising the function “Text Search”. For instance, searching for the word “safety” in the database revealed that it was associated with 116 papers out of 140. The range of the word references occurrence was between 1 to 759. Analysis of the other barriers in the same way revealed that each obstacle was associated with a number of factors (See Chapter 2 for more details). Following the four stages discussed above, a preliminary framework which linked the barriers to full adoption of AVs to the AV system architecture was created. A copy of the framework (as presented in Chapter 2) is included here for ease of reference (See Figure 3-10).

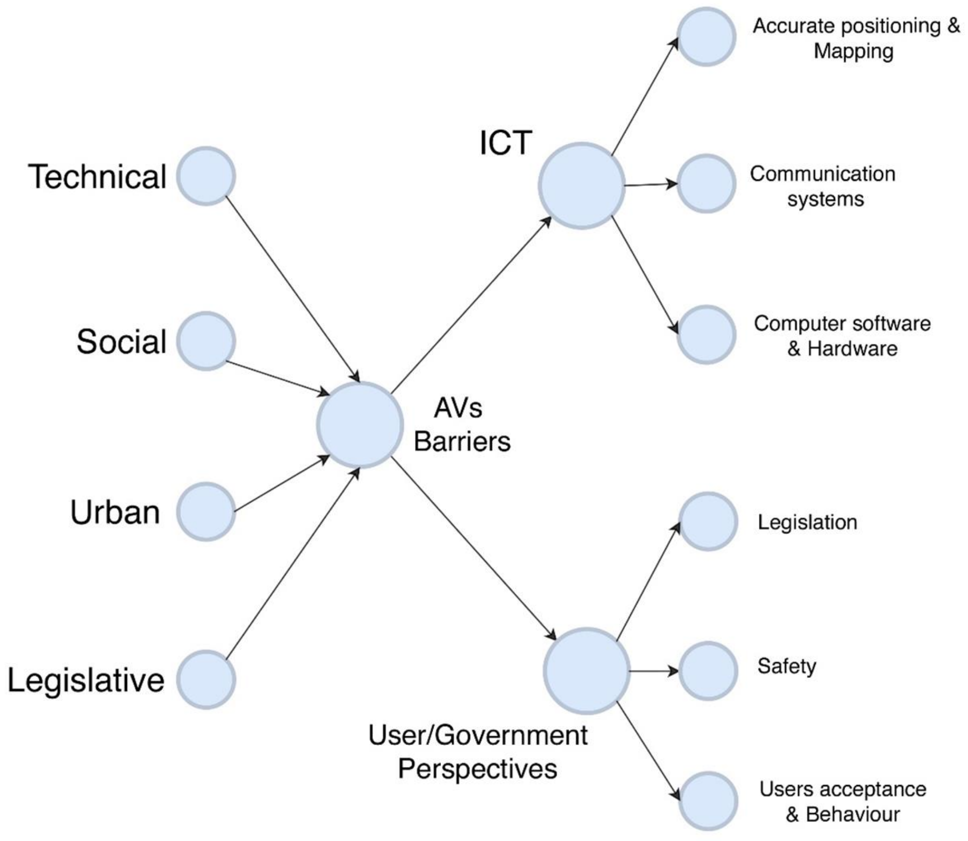


Figure 3-10. Key barriers preventing full adoption of AVs and their (Bezai et al., 2021).

3.9.2 Phase II

Figure 3-11 provides an overview of this phase, showing the relationships between the different elements and the ways in which the findings of this stage were informed by and informed other phases.

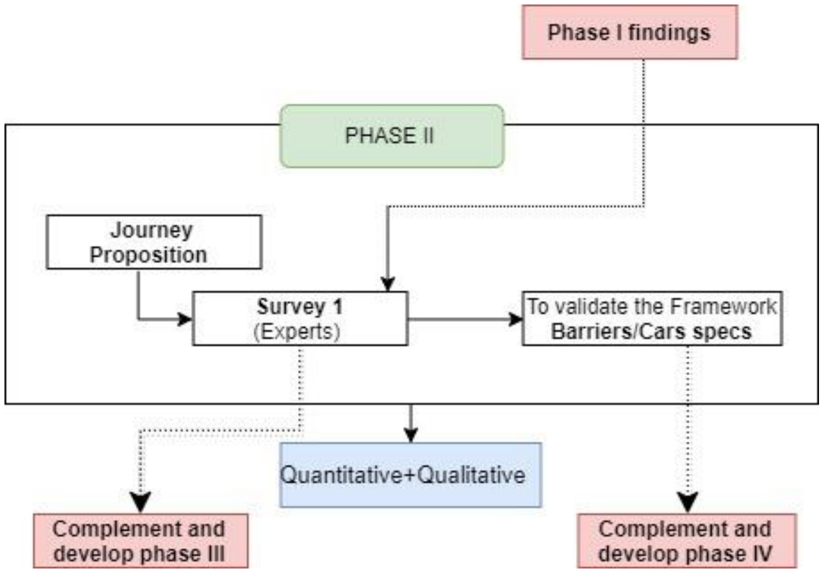


Figure 3-11. Second Phase: Survey 1 to validate the framework and assess urban impact of AVs (Author, 2019).

3.9.2.1 Goal and purpose

The primary purpose of this phase was to validate the preliminary framework created in Phase I. In order to achieve this, a survey was designed and administered to experts in associated fields (urban planners, vehicles' manufacturers, IT specialists, insurance companies, and key decision-makers). This asked the experts to review the preliminary framework to add weight to the validation process and the quality of the findings. In addition, suggestions from the experts were used expand the research enquiries set in the beginning, inform recommendations, and highlight future research opportunities. Thus, this phase aimed to validate the framework but also to align partially with Objective 3. The outcomes of this phase complemented and informed phases III and IV. A list of hypotheses were formulated to be tested (See Chapter 4; 4.3.2 Research hypotheses).

A pilot study was conducted to assess the content before the main survey was administered, and specialist survey design software on an online platform (onlinesurveys.ac.uk) was utilised. NVivo 12 Pro was used to analyse the open-ended questions and SPSS to analyse the closed-ended questions.

3.9.2.1 Sample size

The number and type of experts involved in the survey was key to the success of this study and the identification and validation of the final urban planning framework. According to Okoli and Pawlowski (2004), it is crucial that the right experts are selected; however, there appears to be no consensus in the literature about the most appropriate sample size. Some authors recommend fewer than 50 participants, as the likelihood of error increases with the size of the panel (Witkin,1995; Aldossary, 2015); however, Clayton (1997) suggested that 15 - 30 experts would be acceptable. In this study, 36 experts from a broad range of disciplines, including urban planning, IT, transportation, traffic simulation, road accidents, environmental management, wireless communication, and machine learning, completed the survey. More details about the proportion of respondents in each field are provided in Chapter 4.

3.9.2.2 Survey 1

***Methodology*: Quantitative and qualitative**

***Methods*: Semi-structured Survey; Sampling**

***Tools:* NVivo 12 PRO, SPSS**.

Survey Structure

The survey, entitled: "Autonomous cars adaptation in urban spaces (Barriers, Vehicle specifications, and required Infrastructure)", was structured into five sections. These are shown in Figure 3-12 and described in more detail below. A copy of the survey is provided in Appendix 1.

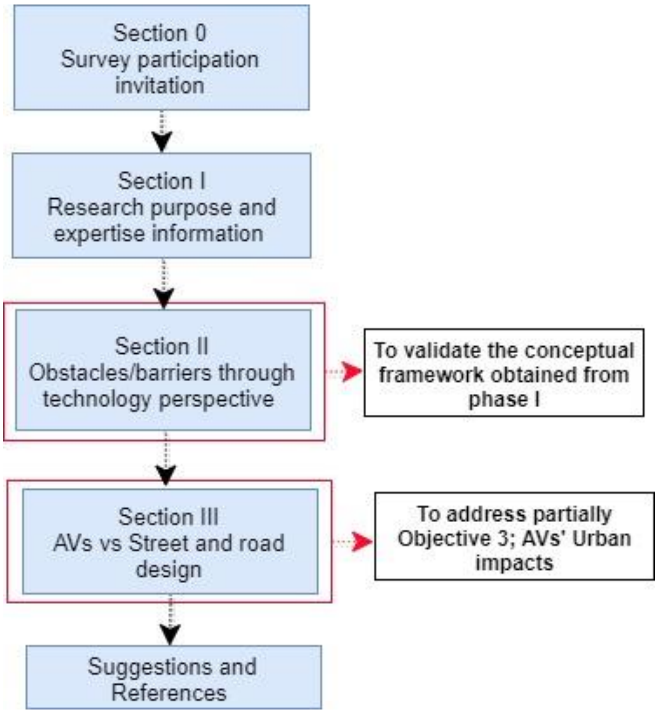


Figure 3-12. Structure and purpose of the experts' survey (Author, 2019).

Section 0: *Survey participation sheet*. This explained who was conducting the research and the potential contribution of the participants. It also provided an overall picture of the thesis but focused on the expected findings from the survey. Information about confidentiality and the anonymity of the participants as well as the data storage was clearly explained. In addition, ethical approval details and contact information were provided (See **Appendix** 1).

Section I: *Research purpose and Personal information*. This provided more details about the scope of the study, emphasising the emergence of AVs, their potential benefits and the barriers to be overcome. This section also stated the reasons why the participants had been selected for the study. Participants were asked to provide certain information, such as job title, area of expertise, and years of experience (See **Appendix** 1).

Section II: *Obstacles/Barriers from a technology perspective*. This section presented the preliminary framework developed in Phase 1 which linked the barriers identified in the literature review to the AV system architecture. However, the framework was presented in a simplified version, as shown in Figure 3-13. The reason behind simplifying the framework was to gather opinions from experts in different disciplines, not all of whom had technical expertise. Thus, the simplification was made to maximise the response rate.

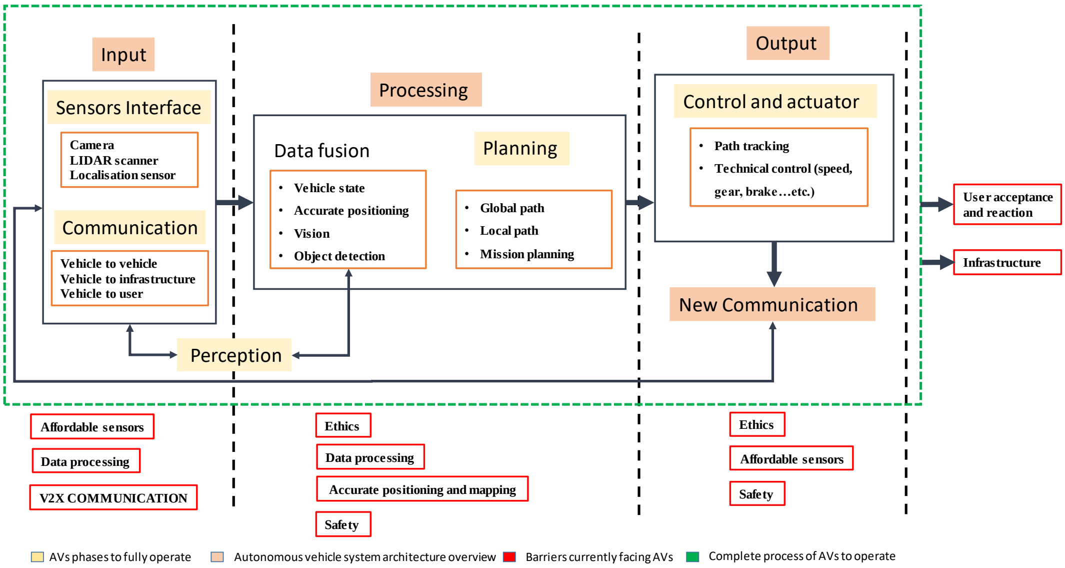


Figure 3-13. Simplified framework showing the AV system architecture combined with the obstacles identified in Phase I (Author, 2019).

The main aim of this section was to validate the preliminary framework developed in Phase I. Experts were introduced to the above framework through closed and open-ended questions, with the former examining the content of the framework in depth. For instance, a closed question was used to ascertain the degree to which the experts agreed or disagreed with aspects of the framework content and an open question asked for suggestions for more content. In addition, this section forecast experts' opinions regarding other anticipated matters, such as their expectation as to when full AVs (Level 4) would operate on our roads and which domains should start acting urgently to facilitate this (e.g., regulation, city planning, vehicle manufacturing).

Section III: *AVs vs Street and road design*. This section partially addressed the third objective which aimed to determine the possible impacts of AVs in our cities. Thus, in the survey, a journey involving an AV moving from point A to point B was proposed in order for the experts to analyse the journey considering the vehicle at its full level of automation (See

Appendix 1). This analysis was done in relation to MFS 1 & 2. Through the imaginary journey, designs issues and design principals were discussed in order to examine the AVs impacts on infrastructure such as traffic lights, road signs, road separation, islands, roundabouts, etc. In addition, this section addressed matters such as ownership, location of car parks (hubs), and the driving mode mixture.

Finally, the last part of the survey was designed to give the participants an opportunity to add any suggestions or expand the research enquiry; this section also contained a list of references.

To conclude, the findings of this phase served to complement and develop phases III and IV. The design of phase III depended on certain variables that were determined in Phase II as these made a significant contribution to the design of the second survey, which was designated for users of AVs.

3.9.3 Phase III

Figure 3-14 provides an overview of this phase, showing the relationships between the elements and the ways in which the findings of the previous stages informed this one.

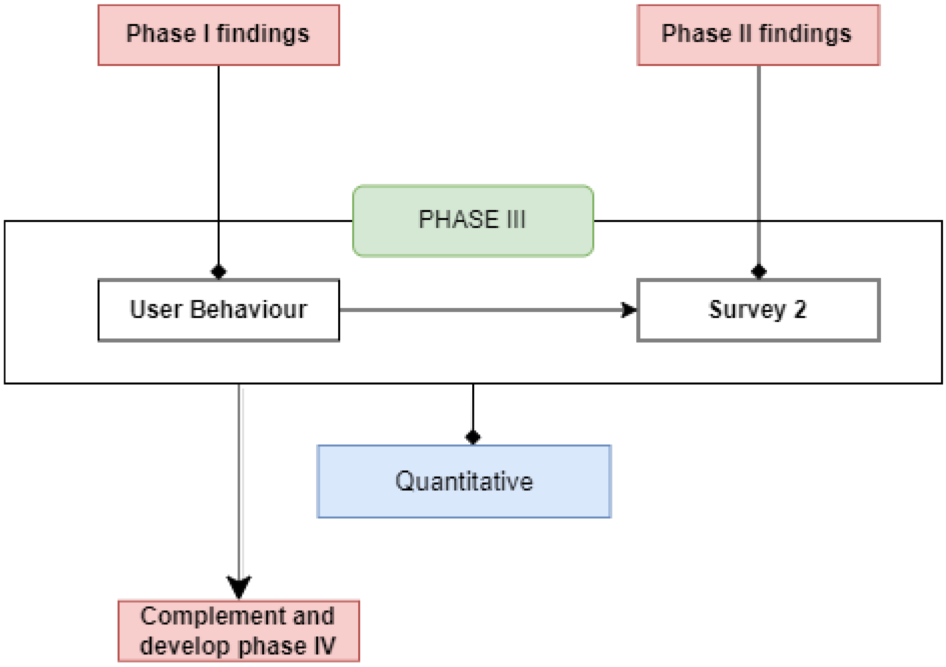


Figure 3-14. Third phase: Survey of AVs and users' point of view (Author, 2019).

3.9.3.1 Goal and purpose

The main purpose of this phase was to address Objective 4, which aimed to analyse and measure AV users' behaviour. To achieve this, an online survey was developed based on the findings of the literature review in Phase I, and various themes were identified.

***Methodology*: Quantitative**

***Method*: structured Survey; Sampling**

***Case study*: Nottingham.**

3.9.3.2 Sample size

The size of the sample to be studied plays a major role in an investigation, both in respect of the time and money required and in the generalisability of the results. Not only is calculating the sample size ethically critical, but it is also effective to get greater satisfaction (J. Kim & Seo, 2013). Figure 3-15 depicts the strategy followed to determine the method to select the probability sampling. Based on the nature and circumstances of the research, systematic sampling was used in this research, and the chain of logic which led to this decision is shown in red in Figure 3-15.

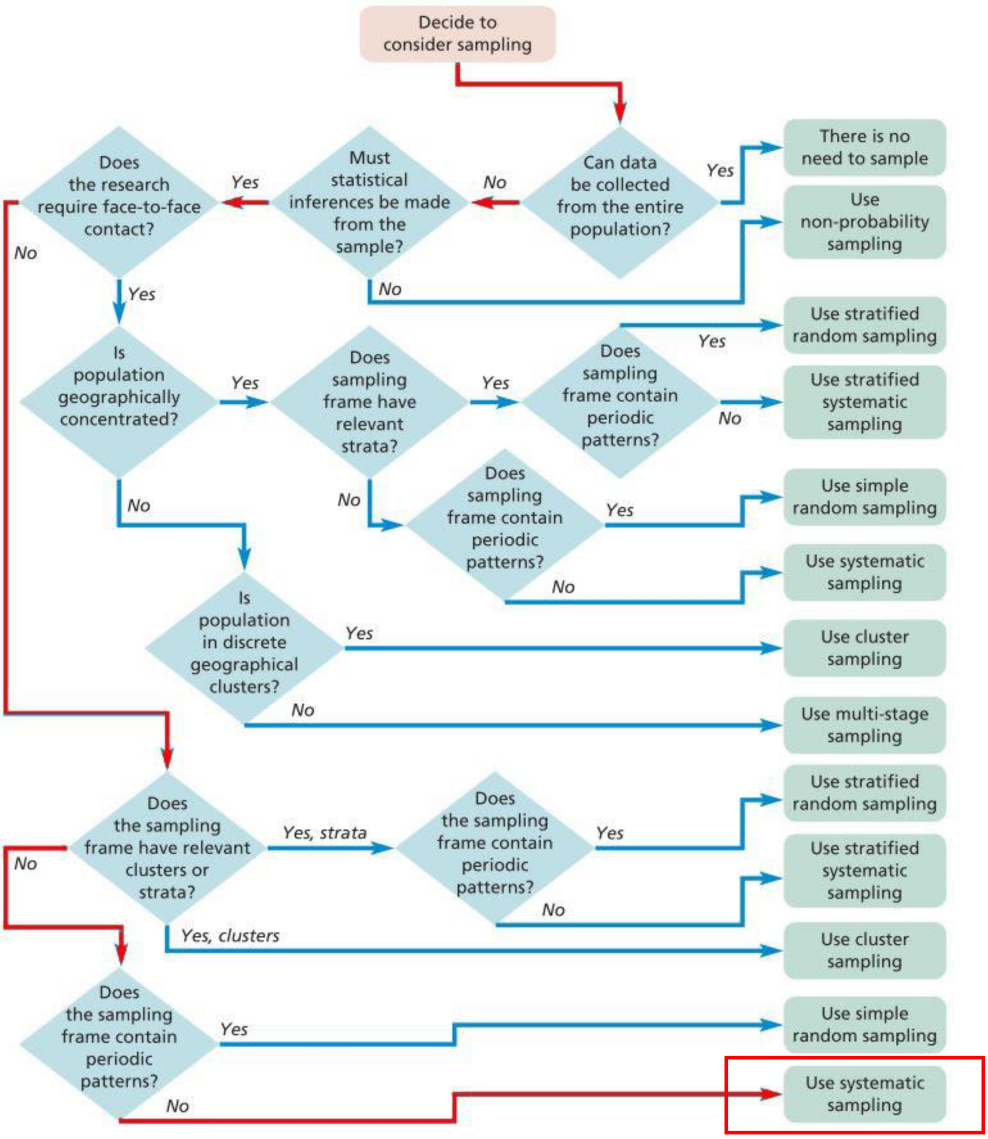


Figure 3-15. Method used to select sample (Adapted from (M. Saunders et al., 2008)

Two methods were used to calculate the sample size employing systematic sampling. The first was manually and was derived using Equation 1 and Equation 2 (explained below) while the second method used the *SurveyMonkey* website tool. The results from both approaches led to the same results; both indicated that 138 respondents were required for this study (See Equation 2 and Figure 3-16).

3.9.3.3 Population size

In mid-2019, the city of Nottingham had an estimated population of 332,900 in the city itself and 828,224 in the county of Nottinghamshire. The former constitute 1.47% of the whole population of England (estimated at 56,286,961) (Nottinghamshire County Council, 2019). As this study focused on Nottingham, the population size taken to calculate the sample was: 332,900. Table 3-13 gives the factors needed to calculate the sample in both methods.

Table 3-13. Factors needed to calculate the sample size (Author, 2019).

Margin of Error	**7%**
Confidence Level	90%
Standard deviation	0.5
Z-score	1.645

a. First method

$$Necessary\ Sample\ Size = \frac{(Z - score)^2 * StdDev * (1 - StdDev)}{(\text{Margin of errors})^2}$$

Equation 1. The equation used to determine the sample size (Reproduced from (Morse, 2000).

$$Sample\ Size = \frac{(1.65)^2 * 0.5 * (1 - 0.5)}{(0.7)^2} = 138.90$$

Equation 2. Calculation of the sample required for the intended study

b. Second method

Figure 3-16 illustrates the sample size calculation using the *SurveyMonkey* calculator, taking the population size to be 332,900, the confidence level 90%, and the margin of error 7. Nevertheless, taking the population of Nottingham (estimated at 332,900) or that of Nottinghamshire (estimated at 828,224) would give the same size of sample required for this investigation, which is 138 respondents.

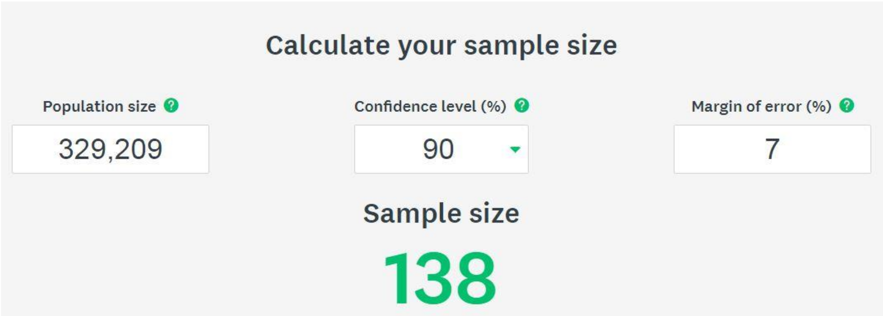


Figure 3-16. Sample size calculation using SurveyMonkey's sample size calculator (SurveyMonkey Inc, 2018).

Survey Structure

In order to study users' behaviour when adopting AVs, an online survey was developed and distributed in Nottingham. The survey title was "Autonomous vehicles and users' points of view" and it was structured into three main sections, as illustrated in Figure 3-17. Each section is described in more detail below.

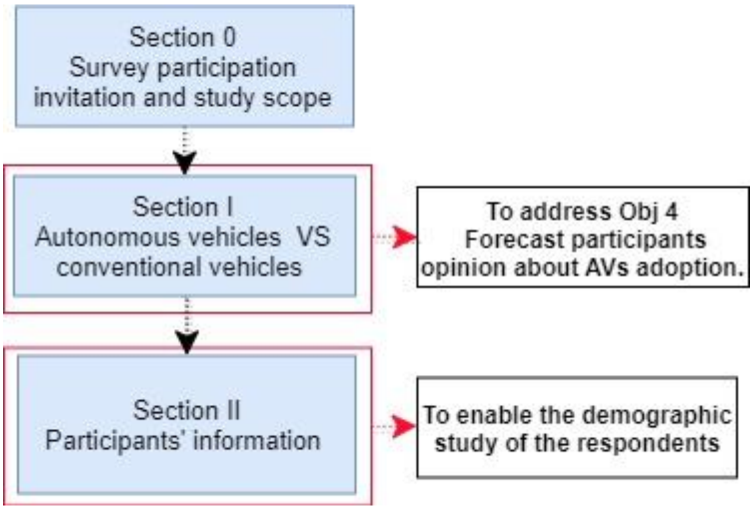


Figure 3-17. Second survey map and structure (Author, 2019).

Section 0: *Survey participation invitation*. This section of the survey explained the reasons for conducting the survey and the scope of the study to give participants a clear picture of the nature of the research. It also explained who was conducting the survey and how the data was gathered and stored anonymously. Information about ethical approval and the right to receive a copy of the survey results was highlighted (see **Appendix** 2).

Section I: *Autonomous vehicles vs Conventional vehicles*. This section was designed using closed-ended questions, with an ‘other’ option in case participants wished to add further criteria. In addition, it contained various themes to be considered by participants, such as mode of moving/travelling around in and between cities, acquaintance with AVs, ownership, global benefits, big data. etc (See **Appendix** 2).

Section II: *Participant information*. This section asked participants to provide demographic data about age, gender, occupation, marital status, level of education, and distance from home to work or place of study. The aim in requesting this information was to study the demographic characteristics of the study sample. The former characteristics were considered independent variables, and were also used to determine whether the participants represented the target population for generalising purposes (M. Saunders et al., 2008).

3.9.4 Phase IV

Figure 3-18 provides an overview of this phase, showing the relationships between the elements and the ways in which the findings of the previous stages informed this one.

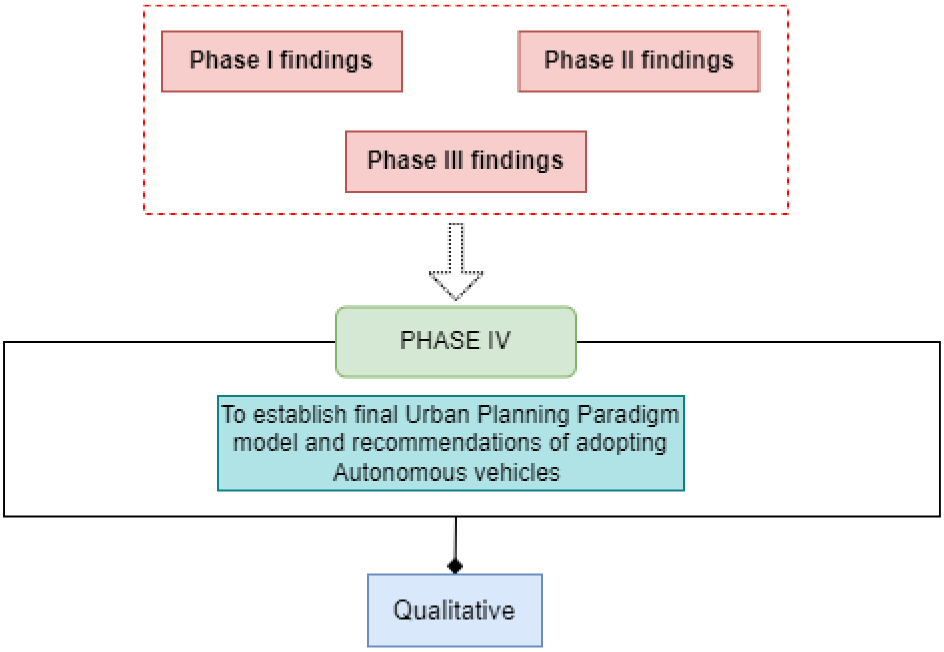


Figure 3-18. Fourth phase: to validate and establish the final urban framework to adopt AVs (Author, 2019).

Goal and purpose:

This phase aligned with the final research objective and its main aim was to combine the findings from each phase in order to develop an urban planning framework to help transportation infrastructure adapt to accommodate AVs. The literature review in Phase I led to the establishment of a preliminary framework which combined technological, social, urban and legislative barriers to AVs with the system architecture. This was then presented to the experts for comment, development and validation in Phase II. The findings of the survey in Phase III (which was shaped by Phases I and II), also informed phase four discussion and the resulting final framework. Thus, the outcomes of all the phases were combined to assist planners, citizens, politicians, and stakeholders in their planning decision-making in respect of AVs.

3.10 Credibility of the Research

To enhance the credibility and acceptance of the research findings, an appropriate methodology and data collection techniques are required (M. B. Miles & Huberman, 1994) as well as a good and consistent research design. The latter is crucial because the it prevents the researcher deceiving himself and drawing invalid conclusions (M. Saunders et al., 2008). In addition, (M. Saunders et al., 2008) stress that in order to decrease this risk, considerations must be given to two specific aspects of the research design: reliability and validity. (M Easterby-Smith et al., 2012) proposed a template linking key philosophical viewpoints with issues relating to validity and reliability. This includes significant questions to enable the researcher to assess the reliability and validity of the methods used and the findings achieved. These questions are illustrated in Table 3-14.

Table 3-14. Question relating to reliability and validity in key paradigms (M Easterby-Smith et al., 2012).

Viewpoint	***Strong Positivist***	***Positivist***	***Constructivist***	***Strong Constructivist***
Reliability	*Has the design eliminated all alternative explanations?*	*Will the measures yield the same results on other occasions?*	*Will similar observations be reached by other observers*	*Is there transparency about data collection and interpretation?*
Validity	*Do the measures correspond closely to reality?*	*Do the measures provide a good approximation to the variables of interest?*	*Have a sufficient number of perspectives been included?*	*Does the study clearly gain access to the experiences of those in research setting?*

This research has adopted two main research paradigms based on the ontological and epistemological assumptions of the researcher, Post-positivism and Constructivism. Thus, as per Table 3-14, two main questions need to be asked to assess reliability. Likewise, to assess validity two questions are considered.

Using diverse but complementary methods makes it easier to detect inconsistencies in the data; thus, unreliability can be diminished (Abowitz & Toole, 2010). For instance, in this study, the content analysis method was used to identify the current barriers to AV adoption and a survey was designed for the experts to reflect on the resulting framework. This helped to ensure the consistency of the data collected and also the validity of the findings. However, (Potter & Levine-Donnerstein, 1999) argue that the reliability and validity of content analyses is not restricted to theory-based coding schemes and principles set by experts, and researchers must also clearly understand the content to be analysed and the function of theory in their studies. Therefore, in this study, the content to be analysed was carefully selected from various type of publications, such as journal articles, books, book sections, reports, webpages and conference proceedings, and only recent publications were selected.

3.10.1 Reliability

Reliability alludes to the degree to which the information gathering strategies or analysis techniques utilised in a study produce coherent results. Adopting positivist and constructivist philosophical viewpoints in this study led to the employment of both quantitative and qualitative methodologies, namely content analysis, document analysis, and surveys, to address the objectives of this research. In order to achieve reliability in this study, the researcher tried to eliminate the chief causes of unreliability. These have been identified as: participant error, participant bias, observer error and observer bias by (Robson, 2016). These causes and the steps taken to mitigate them are presented in Table 3-15.

Table 3-15. Unreliability causes and the precautions taken to minimise them (Author, 2019).

Causes / Methods	**Participant error**	**Participant bias**	**Observer error**	**Observer bias**

Survey 1&2	The survey was distributed online so participants had the freedom to complete it at their own convenience.	The surveys aimed to forecast opinions about AVs. The sample was a random sample, using systematic sampling to avoid bias.	Questions were clear, structured or semi-structured, and they were not deceptive. Moreover, they were developed to elicit the same type of information.	The researcher was aware of the threats to reliability and tried to control them. Statistics analysis was performed, such as correlation and Cronbach's Alpha measurement to verify the data.
Document and content analysis	N/A	N/A	The study defines clearly the content to be analysed and employs an empirical approach using NVivo 12 Pro following theory-based coding schemes	A data base of sources is built contains various type of publications based on set objectives such as year of publication and relevance of the abstract.

3.10.2 Validity

According to (Robson, 2016) validity is *"concerned with whether the findings are 'really' about what they appear to be about".* In other words, validity indicates how solid the research is, and this applies to both the research design and the selected research methods. For instance, validity in data gathering implies that the research results indeed represent the phenomena being studied. Particular care was taken to ensure the validity of the data gathered in both of the surveys in this study, and a four-stage construction process was followed, as developed by (M. Saunders et al., 2008) from Foddy (1994). These stages are illustrated in Figure 3-19. This process was used to ensure that the questions were comprehended by the participants in the manner intended by the researcher and that the responses given by the participants were comprehended by the researcher in the manner they intended. Hence, following the four stages ensured the validity of the questions. In addition, specialist online survey design software (onlinesurveys.ac.uk) was utilised and a pilot study was conducted to assess the content, criterion-related and construct validity of the questions.

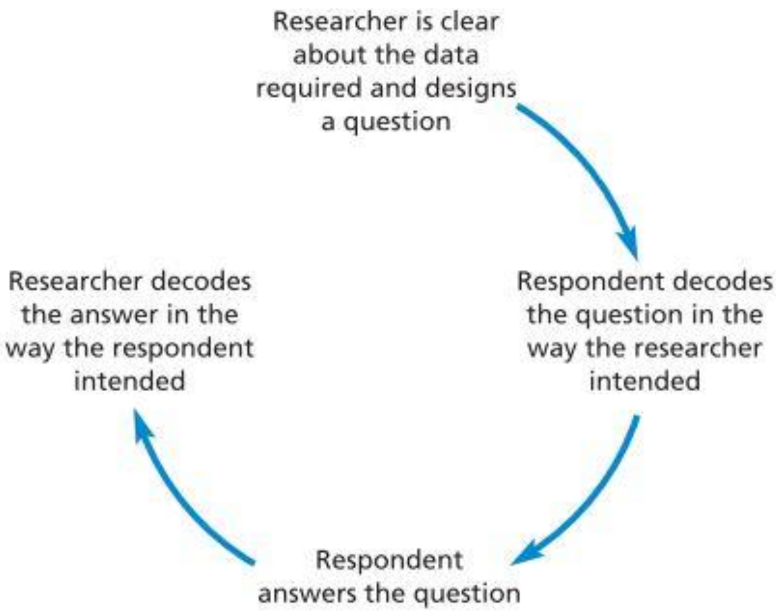


Figure 3-19. Process used to ensure the validity of the survey questions (M. Saunders et al., 2008)

3.11 Ethical Considerations

Ethics are the standards or measures that guide our moral decisions and choices in respect of our behaviour as well as our relationships (Blumberg, 2008). There is no doubt that research can have an adverse effect on individuals' lives; hence, researchers should carefully consider the potential impacts of the research outcomes and how they should act and behave so that no damage is caused to the study participants or to society in general (McNeill, 2005). (M. Saunders et al., 2008) believe that research ethics are identified with inquiries about how we perceive and explain our research topic, design, structure, data collection, data storage, analyse and write research outcomes in a clear and responsible manner. This means that researchers must ensure that their research design is "*both methodologically sound and morally defensible to all those who are involved*" (M. Saunders et al., 2008). Deontological and teleological are two dominant philosophical views regarding morals. The former is symbolised by Aristotle's ethics of virtue, whereas the latter is exemplified by Kant's ethics. The two are considered to be incompatible: *"either the good or the right"* (Ricoeur, 1987). The deontological view claims that unethical research can never be justified by the ends, while the teleological view argues that the ends can justify the means if the benefits of the research outcomes outweigh the cost of acting unethically (M. Saunders et al., 2008). In light of this, a deontological philosophy was adopted for this study, and the following broad ethical issues were considered (McNeill, 2005).

Firstly, all the research participants were fully informed about the research aim and purpose. Both surveys included a consent page to explain the aim of the research and what kind of results the researcher was expecting (See Appendix 1 & 2). Informing participants in this way enabled them to make informed decisions about whether to take part or not. As this study did not deal with children or people with learning disabilities, participants were assumed to have given informed consent if they moved on to the next screen. Participants were also informed that they could receive a copy of the survey results on request.

Secondly, there are two schools of thought amongst sociologist regarding whether it is acceptable to hide information from participants in order to maximise research outcomes. The first school believes that *"Information must not be kept from those taking part in the research"* (McNeill, 2005)., nor should participants be misled about the research intentions. The second school argues that this may not be necessary if more data can be collected via a less honest approach and the value of the data is sufficient to justify this. Nevertheless, this study adopted an honest approach and efforts were made to ensure that none of the information provided to participants was misleading.

Thirdly, research involving human participants can be intrusive in its nature, so the privacy of participants must be protected. In the present study, no personal or sensitive data about participants was required, such as their names, addresses or phone numbers. Participants were also informed that they had the right to withdraw their participation at any time.

Fourthly, confidentiality is an important element in data collection, and participants need to be aware of who can use their data (Wiles et al., 2008). Moreover, confidentiality and anonymity can increase the value of the data because participants feel more comfortable (McNeill, 2005). In this study, no personal data were collected and participants were made aware that their participation would be confidential and anonymous, and information would only be shared amongst the research team for educational purposes. Likewise, all the data gathered from their participation was stored in a secured computer and password protected. In addition, no participants will be identified in any publication arising from the study.

Fifthly, participants must always be protected from any kind of physical harm. This usually happens when an experiment is involved; however, sociologists believe that harm is not always physical, and emotional harm could be caused, for example, through insensitive questions or by triggering memories about something participants would prefer to forget. In this study, there was no physical engagement with participants, the only contact was online or through email, and no experiments were involved.

Finally, considerations of legality and immorality were not material to this study because no sensitive/personal data were required, and there were no possible situations where the researcher could deviate from the research topic and the study purpose.

Ethical approval for this study was granted by the Joint Inter College Ethics Committee of Nottingham Trent University. All research participants were notified of this in writing.

3.12 Conclusion

The chapter has provided a comprehensive overview of the methodology adopted for this study. It began with discussion of the philosophical research positions and the major research paradigms. It explained the ontological and epistemological assumptions of the study which led to the identification of the post-positivist and constructivist paradigms as most suitable for this research. Post-positivism was chosen as the study involves testing several hypotheses regarding the impact of AVs on cities, urban planning, and AV users' behaviour. Constructivism was adopted since it aligns with the study's engagement with multi-disciplinary experts to analyse the preliminary framework and assess the impact of adopting AVs on urban planning. As a result, a mixed-methods research methodology was adopted using a multilevel triangulation design model. This resulted in a four-phase implementation, involving the primary research methods: (i) content analysis and document analysis, (ii) semi-structured survey and sampling (experts) (iii) semi-structured survey and sampling (public) and (iv) creation of the final urban planning framework and formation of recommendations. The outputs of each phase informed the subsequent phases; thus, the final urban planning framework was developed in light of the findings from each phase of the research.

Chapter 4: AVs Urban Impact Analysis and Conceptual Framework Validation: Survey 1 results and discussion

Content

Chapter 4: AVs Urban Impact Analysis and Conceptual Framework Validation: Survey 1 results and discussion.

4.1 Introduction

The findings from the literature review informed the creation of a survey for experts in a range of disciplines associated with AVs which was intended to address Objective 1 and part of Objective 3. Another aim of the survey was to validate the conceptual framework developed in Chapter 2, so a simplified version of the framework was presented to the experts, and their opinions on its content and validity were sought (the simplification was for the benefit of the non-technical experts). Since the overall aim of this research is to create an urban planning framework for AVs, a journey through the centre of Nottingham was also proposed in order for the experts to evaluate the likely impacts of AVs on streets, road designs, and metropolitan areas in general. This chapter presents the results of the expert survey and analysis of a series of hypotheses that were formulated and tested to validate the framework and explore the experts' opinions in more detail.

4.2 Profile of the Expert Participants

A total of 36 experts participated in this survey, with an average of 12 years of expertise in a range of disciplines, including urban planning, IT, transportation, traffic simulation, traffic accidents, environmental management, wireless communication, and machine learning. The proportion of respondents in each discipline is shown in Table 4-1.

Table 4-1. Summary of the areas of expertise of the participating experts. (Author, 2021)

Technology (8 experts)	**Planning/Environment (16 experts)**	**Transportation/ Manufacturing (6 experts)**	**Users and Others (6 experts)**
• Information Technology • Machine Learning, Multi-agent Systems • Wireless communication and Machine learning • Artificial Intelligence.	• Architecture and urban planning • Urban design and city planning • Digital architectural Design • Civil Engineering, Construction	• Platooning • Highway, Traffic and Transportation Engineering • Traffic Simulation • Vehicle manufacturing • Mechanical Engineering	• Traffic accidents Expert • Product Design • Business Sustainability and product longevity • Human behaviour

	Management, and Materials • Environmental Management • Smart cities and AEV technologies • Design expertise regarding the built environment	• Building design, performance, and efficiency.

4.3 Survey Structure and Research Hypotheses

SPSS and NVivo PRO 12 were used to analyse the data collected, and this enabled a number of hypotheses to be tested. The structure of the survey and the development of these hypotheses are described below.

4.3.1 Survey structure

The survey was divided into two main sections according to the principle themes for investigation:

Section I: AV barriers and framework validation

- General barriers to AV adoption
- Framework evaluation
- Time expectations for full AV adoption
- Domains which need to be developed first

Section II: Impacts in urban areas; Street and road designs

- Design principles and design issues likely to be *affected* by AVs
- Design principles and design issues likely to be *removed* by AVs
- AVs' impacts on MFS guidelines for design
- AVs and Car ownership
- AVs and Parking/storage
- Hub Locations
- AV implementation
- Autonomous VS manual driving

4.3.2 Research hypotheses

A total of ten hypotheses were developed: five in each section. These explored the barriers to AV adoption, the substance of the proposed framework, potential timescales for AV adoption, and the steps required to enable this. These are set out in Table 4-2 & Table 4-3, along with the questions created and the sub-hypotheses generated.

Table 4-2. Summary of the hypotheses (Section I) (Author, 2021)

Hypotheses (Alternative)	**Sub-Hypotheses**
Hypothesis 1 *To study the relationship between experts' rating and ranking of the AV barriers and their fields of expertise*	**Questions 1 & 6** **a.** Experts *rate* the importance of the barriers based on their area of expertise (Q1: area of expertise). **Questions 1 & 7** **b.** Experts *rank* the importance of the barriers based on their area of expertise (Q1: area of expertise).
Hypothesis 2 *To study the relationship between the experts' opinions about the substance of the proposed framework and whether they suggest other barriers need to be investigated*	**Questions 5 & 8** **a**. Experts who expressed the view that the proposed framework has the right number of barriers will not suggest investigating further obstacles. **b.** Experts who expressed the view that the proposed framework has a small number of barriers will suggest investigating further obstacles.
Hypothesis 3 *To study the relationship between the experts' opinions about whether further investigation of AV barriers was required and their expectations about the time frame for full AV implementation.*	**Questions 5 & 9** **a.** Experts who agreed that more barriers needed to be investigated, anticipate that full AVs will be ready in 11-15 years, 16-29 years, or after 30 years. **b.** Experts who said no more barriers needed to be investigated, anticipate that full AVs will be ready in 0-5 years or 6-10 years. **c.** Experts who said that they are not sure whether there is a need to investigate other barriers anticipate that full AVs will be ready after 30 years.
Hypothesis 4 *To analyse the relationship between the experts' areas of expertise and their opinion about which domain needs to be developed first.*	**Questions 1 & 10** The majority of experts (all areas of expertise) are likely to think that the "Vehicle Manufacturing" domain should be developed first.

Table 4-3. Summary of the hypotheses, (Section II) (Author, 2021).

Hypotheses (Alternative)	Sub-Hypotheses
Hypothesis 5 *To analyse the relationship between the design principles and design issues which will be affected and those which will be removed.*	**Questions 11 & 12** **a.** Design principles and design issues which were identified as being affected by AV implementation will be removed. (To see whether the design principles and design issues being affected will be removed in the future, "transition")
Hypothesis 6 *To analyse the relationship between the affected and removed design principles and design issues and the Design guidance (MFS 1)*	**Questions 11, 12 & 13** The impact of AVs on these design principles and design issues will have a significant impact on design guidance.
Hypothesis 7 *To examine the relationship between the experts' choice of domain which needs to be prioritised for development and whether they expect future AV/Car ownership to increase, decrease or remain the same.*	**Questions 1, 10 & 14** **a.** Experts who selected "City Planning" as the first domain to develop expect AV/Car ownership to increase. **b.** Experts who selected "regulation" as the first domain to develop expect AV/Car ownership to decrease. **c.** Experts who selected "Vehicle manufacturing" as the first domain to develop expect AV/Car ownership to increase.
Hypothesis 8 *To study the relationship between parking types and location and their effect on future AV ownership*	**Type of Parking: Questions 14 & 15** **a.** AV ownership will increase if underground/overground parking hubs for AVs are created. **b.** AV ownership will decrease if underground/overground parking hubs for AVs are created. **Location of Parking: Questions 14 & 16** **a.** AV ownership will increase if parking areas are located in each neighbourhood. **b.** AV ownership will decrease if parking areas are located in the city centres or on the outskirts.
Hypothesis 9 *To analyse the relationship between manual driving and AV ownership*	**Questions 14 & 18** **a.** Experts who said "Yes" manual driving should be banned are expecting AV ownership to decrease. **b.** Experts who said "No" manual driving should not be banned are expecting AV ownership to increase.

4.4 Survey Results

4.4.1 Section I: AV barriers and framework validation

The first part of the survey asked the experts to give their opinions regarding the potential obstacles to full AV adoption and the contents of the conceptual framework from the perspective of their different disciplines. They were also asked when they expected AVs to be fully operational, and which domains (urban planning, regulations, or vehicle manufacturing) should be prioritised for development. Their responses are described below.

4.4.1.1 General barriers that prevent AV adoption

Table 4-4 illustrates the word frequency and the weighted percentage of the answers collected from the experts in answer to the first question: “Generally speaking, what do you think are the barriers that prevent us having autonomous vehicles on our roads?” (Q2). The results show that “*safety*”, “*road*”, “*infrastructure*”, “*operational*”, “*system*” and “*lack*” were used most frequently, and were mentioned at least seven times by the experts. Safety was the most commonly used word, mentioned 14 times and used by around 40% of the experts.

Clustering analysis using NVIVO was then conducted to classify the words, with the word frequency grouping criteria set to “With generalisation”. The reasoning behind this was to group the barriers under different themes based on their general meaning in context. Four main groups emerged from this analysis: ‘Needs and Areas’, ‘Infrastructures & Operations’, ‘Human Behaviour & Knowledge’, and ‘Technology, Communication and Interaction’. The results are shown in Table 4-5.

Table 4-4. Word frequency of responses to Q2: "Generally speaking, what do you think are the barriers that prevent us having autonomous vehicles on our roads?" (Author, 2021)

Word	Count	Weighted Percentage (%)
safety	14	5.17
road	13	4.80
infrastructure	9	3.32
operational	9	2.95
system	8	2.95
lack	7	2.58
issues	6	1.91
cost	5	1.85
human	5	1.85
control	5	1.48
design	4	1.48
develop	4	1.48
potential	4	1.48
technology	4	1.48
user	4	1.48
need	4	1.17
combine	3	1.11
communication	3	1.11
pedestrians	3	1.11
use	3	1.11
considering	4	0.98
basic	2	0.74
change	2	0.74
City	**2**	**0.74**
compromise	2	0.74
computer	2	0.74
drop	2	0.74
general	2	0.74
hack	2	0.74
increased	2	0.74
interaction	2	0.74
location	2	0.74
passengers	2	0.74
perception	2	0.74
person	2	0.74
prevent	2	0.74
solution	2	0.74
still	2	0.74
transport	2	0.74
driving	3	0.62
aspect	2	0.55
deal	2	0.55
feel	2	0.55
introducing	2	0.55
limited	2	0.55
precedents	2	0.55
acceptance	2	0.43
pick	2	0.43

Table 4-5. Classification of the barriers by concept (Author, 2021)

Needs and Areas	Infrastructure & Operations	Human Behaviour & Knowledge	Technology, Communication and Interaction
• Cost • Requirement • Location • Support • Infrastructures • Ethics • Conviction • Ownership reduction • Traffic • Authority • Security • Accountability • Legislation • Maintenance • Standards	• Roads • Pick/drop • Furniture • Compromise existing infrastructures • Develop • Design • Energy • Charging stations • Centre for pedestrians info	• Awareness • Integration • Perception • Ability • Capacity • Operate • Control • Age • Change • Technophobia/ aversion • Trust • Manuel driving preference • Use	• Performance • Processing • Immediacy response • Hack • Adapt to variations of layouts • Computer • Device • Reliability • System • Interface

4.4.1.2 Framework evaluation

The next set of questions (Q4 to Q8) asked the experts to evaluate the contents of the framework developed in Chapter 2, which linked the barriers identified in the literature with the AV system architecture. These questions and the responses received are described below.

Q4: To what extent do you agree or disagree with the substance of the proposed Framework?

Overall 83.30%. of the expert respondents agreed with the substance of the framework: 11.10% strongly agreed, 58.30% moderately agreed, and 13.90% slightly agreed. 16.70% of the experts neither agreed nor disagreed.

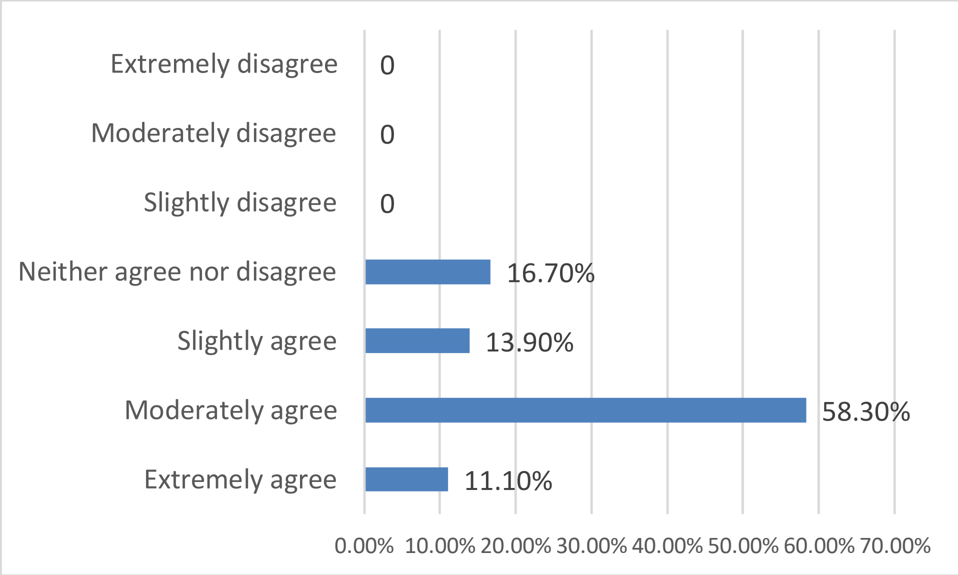


Figure 4-1. Q4: To what extent do you agree or disagree with the substance of the proposed Framework? (Author, 2021)

Q5: Does this Framework show too many, too few, or about the right number of barriers and vehicle specifications?

This question sought to determine if the number of obstacles identified in the study was sufficient or whether further investigation was required to add other obstacles. The results are shown in Figure 4-2.

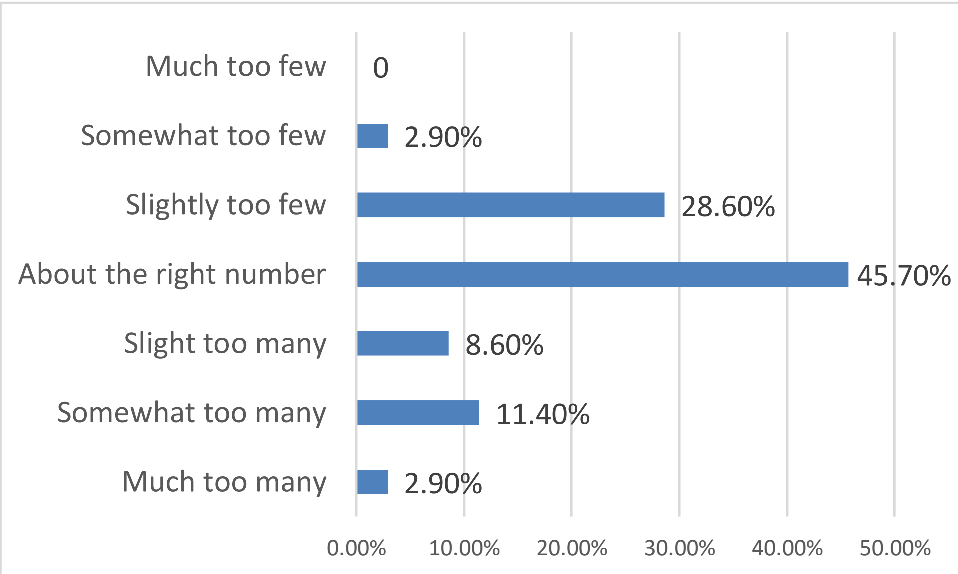


Figure 4-2. Expert responses to Q5: Does this Framework show too many, too few, or about the right number of barriers and vehicle specifications? (Author, 2021)

As can be seen, 45.70% of the respondents thought the study thought the number of barriers and vehicle specifications was about right. 28.60% thought the number was too small, and 8.60% thought it was too high. The hypothesis that there is a relationship between the expressed opinions about the right number of AVs barriers and vehicle specifications and whether there should be more to be investigated (Hypothesis 2) is examined in Section Hypotheses Testing and Analysis).

Q6: How do you rate the following barriers based on their level of importance to resolve?

This question asked the experts to rate seven obstacles to self-driving cars extracted during the literature review study using a five-point scale (from 'extremely important' to 'not important at all'. The obstacles identified were: Data processing (computer software & hardware); Safety; Affordable sensors; V2X communication; Accurate positioning and mapping; User acceptance and behaviour; and Ethics. The experts were also asked to indicate if they thought an obstacle should be dropped from the study because it wasn't considered sufficiently important. The results are shown in Figure 4-3 and Table 4-6.

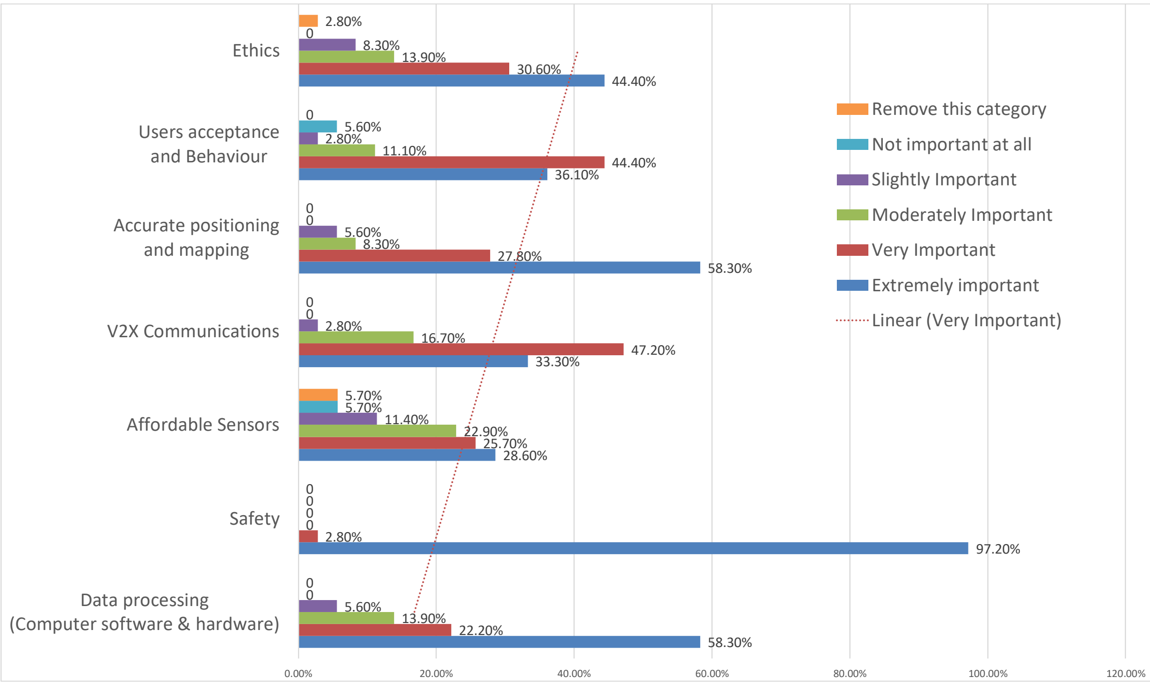


Figure 4-3. AV barriers rated based on their importance according to the experts (Author, 2021).

Table 4-6. Data table used for Figure 4-3: Q6: How do you rate the following barriers based on their level of importance to resolve? (Author, 2021)

	Data processing (Software & hardware)	Safety	Affordable Sensors	V2X Communication	Accurate positioning and mapping	Users acceptance and Behaviour	Ethics
Extremely important	58.30%	97.20%	28.60%	33.30%	58.30%	36.10%	44.40%
Very Important	22.20%	2.80%	25.70%	47.20%	27.80%	44.40%	30.60%
Moderately Important	13.90%	0	22.90%	16.70%	8.30%	11.10%	13.90%
Slightly Important	5.60%	0	11.40%	2.80%	5.60%	2.80%	8.30%
Not important at all	0	0	5.70%	0	0	5.60%	0
Remove this category	0	0	5.70%	0	0	0	2.80%

As Figure 4-3 and Table 4-6 show, most of the obstacles were assessed as either extremely or very important. Safety was identified as the most important obstacle, with 97.2% of experts regarding it as extremely important and the rest saying it was very important. As for obstacles which should be removed because they weren't considered sufficiently important, a small proportion of respondents suggested that "affordable sensors " and "ethics" could be removed; 5.70% and 2.80%, respectively.

Q7: How do you rank the following criteria (please rank, with 1 being the most important and 7 being the least important)?

The next question asked the experts to rank the AV barriers in order of importance (with 1 being the most important). The results are shown in Figure 4-4 and Table 4-7.

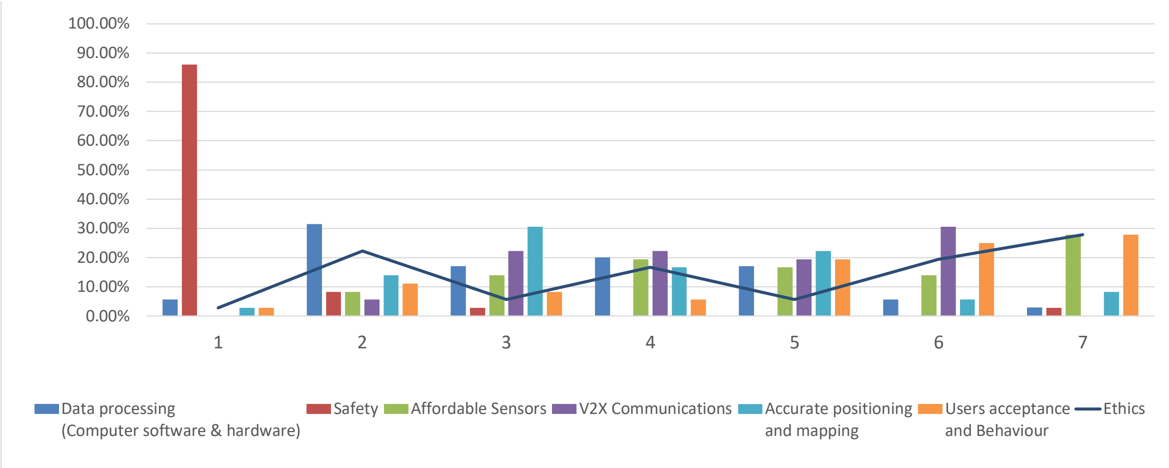


Figure 4-4. AVs barriers ranked in order of importance from 1 to 7 (Author, 2021).

Table 4-7. Data table used for Figure 4-5: Q7: How do you rate the following criteria (rank with 1 being the most important, and 7 being the least important)? (Author, 2021).

Rank	**Data processing (Computer software & hardware)**	**Safety**	**Affordable Sensors**	**V2X Communication**	**Accurate positioning and mapping**	**Users acceptance and Behaviour**	**Ethics**
1	5.70%	86.10%	0	0	2.80%	2.80%	2.80%
2	31.40%	8.30%	8.30%	5.60%	13.90%	11.10%	22.20%
3	17.10%	2.80%	13.90%	22.20%	30.60%	8.30%	5.60%
4	20.00%	0	19.40%	22.20%	16.70%	5.60%	16.70%
5	17.10%	0	16.70%	19.40%	22.20%	19.40%	5.60%
6	5.70%	0	13.90%	30.60%	5.60%	25%	19.40%
7	2.90%	2.80%	27.80%	0	8.30%	27.80%	27.80%

The highlighted percentages represent the highest rank by experts for each barrier.

As was expected, “safety” was ranked first as the most crucial barrier (86.1%). “Data processing (computer software and hardware)” was ranked second (31.40%), closely followed by “accurate positioning and mapping” (30.60%).As for the other barriers, their ranking ratios were close: “V2X communication” (22.20%), “Users acceptance and behaviour” (19.40%), and “Ethics” (19.40%). “Affordable sensors” was regarded as least important among all the proposed obstacles (27.80%). Therefore, based on the experts' opinions, the AVs barriers can be ranked as follow:

1. Safety
2. Data processing (Computer software and hardware)
3. Accurate positioning and mapping
4. V2X communication
5. Users acceptance and behaviour
6. Ethics
7. Affordable sensors

Hypothesis 1.2 explores how these barriers were ranked and whether the experts' field of specialisation affected the above sorting.

Q8: Do you think there are more barriers and vehicle specifications to be investigated, either with a direct or indirect effect?

After rating and ranking the AV barriers, the experts were asked if they thought there were more barriers and vehicle specifications to be investigated. The results are shown in Figure 4-6.

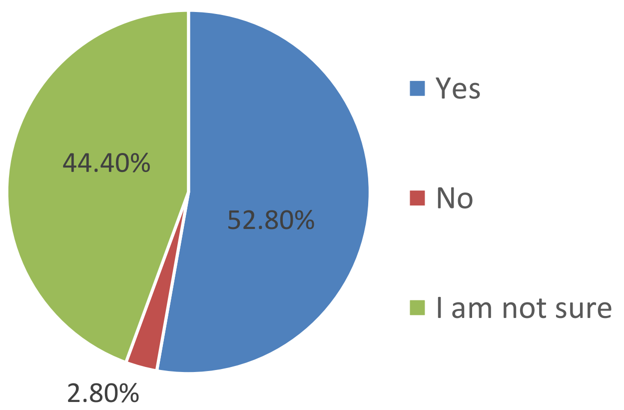


Figure 4-6. Q8: Do you think there are more barriers and vehicle specifications to be investigated, either with a direct or indirect effect? (Author, 2021)

52.80% of experts believed that there were further barriers and vehicle specifications to be investigated compared to just 2.80% who said ‘No’. However, 44.40% of the respondents were not sure whether other barriers and specifications should be investigated.

4.4.1.3 Time expectations for full AV operation

Many automakers are racing to develop AVs, and there is an expectation that full AVs will be run on roads by 2030 (Hyperdrive, 2020). As a result, the experts were asked about their expectations of when AVs will be fully operational on our roads. As shown in *Figure 4-7*, five categories were suggested (0-5 years, 6-10 years, 11-15 years, 16-29 years, or after 30 years) and an “Other” option was also provided. The largest proportion of experts (30.60%) selected 6-10 years, with 22.20% expecting to see full AVs on the roads within 16 - 29 years. As for the remaining proposed time categories, their results were similar.

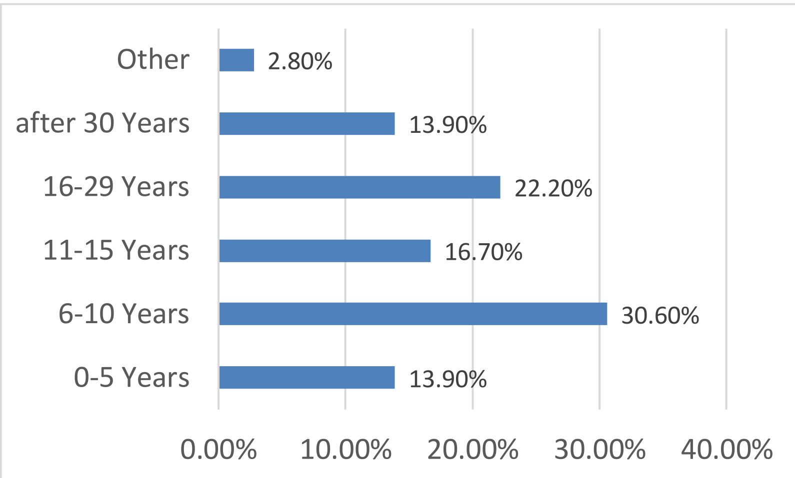


Figure 4-7. Q9: When do you expect autonomous vehicles will be operating fully on our roads? (Author, 2021)

4.4.1.4 Domains which need to be developed first

To adopt AVs in our cities successfully, many aspects and domains need to be developed. These can largely be classified into three categories: (i) the planning of urban areas and towns, (ii) regulations, ethics, and legislative matters related to AVs and their use, and (iii) vehicle manufacturing (technology). The experts were asked which of these domains should be developed first, and also given an 'Other' option. The results are shown in Figure 4-8

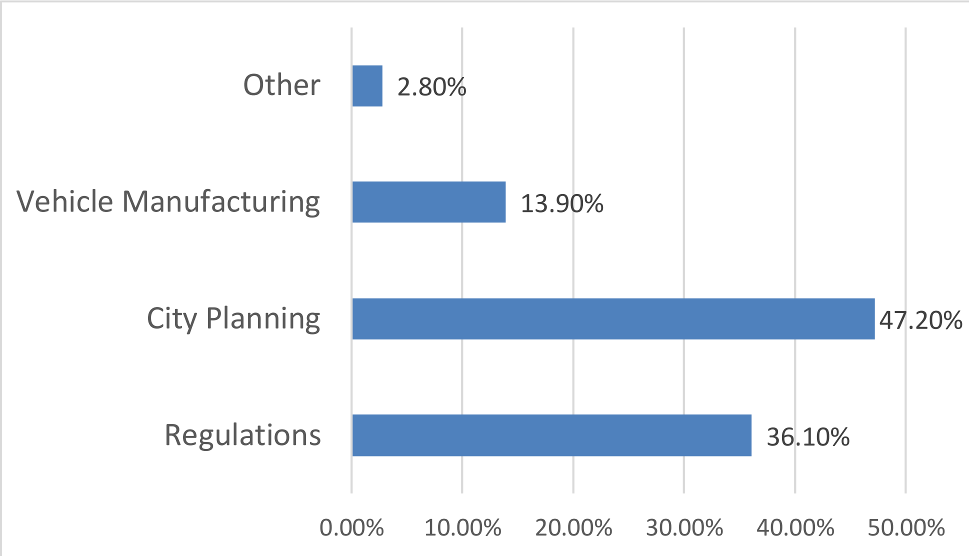


Figure 4-8. Experts' views of the domains which should be prioritised for development (Author 2021)

The results indicate that city planning was the most popular choice amongst the experts, with 47.20% saying that it should be developed first, followed by regulations (36.10%). Interestingly, vehicle manufacturing was chosen as the least urgent domain at 13.90%. Experts might believe that the technology will mature eventually, and the most critical domain should instead be city planning. However, in order to remove any suspicion that the large number of urban planning respondents (16) may have affected these results, the fourth hypothesis studies the relationship between the experts' specialities and their choice of the field to be developed first.

4.4.2 Section II: AVs' impacts on urban areas, streets, and road design

According to Young et al., (2010), in general streets and roads occupy three-quarters of public spaces, so their design has a considerable influence on the quality of individuals' lives. It also means that any adaptations required to accommodate AVs will affect a large proportion of our public space. As a result, a key aim of the second part of the survey was to study the possible impacts of AVs in urban areas, taking into account full autonomy i.e., Level 4. In order to examine these within a real-life context, a 6-minute journey covering 0.7 miles through the centre of Nottingham was presented to the experts, and they were asked to consider how street design elements such as traffic lights, road signs, roundabouts, and intersections would be affected.

The questions in this section were developed using MFS 1 & 2 (Transport, 2007; Young et al., 2010), a manual which has always focused on prioritising pedestrians in urban areas. Based on MFS 1's vision, the literature review findings, and the proposed journey (see Figure 4-9), the following themes are discussed in this section:

- The design principles and design issues which will be *affected* by AV adoption
- The design principles and design issues which will be *removed* by AV adoption
- AVs impacts on the MFS guidelines for design
- AVs and overall car numbers/ownership
- AVs and parking/storage
- AV Hub locations
- AV implementation phases
- Autonomous vs manual driving

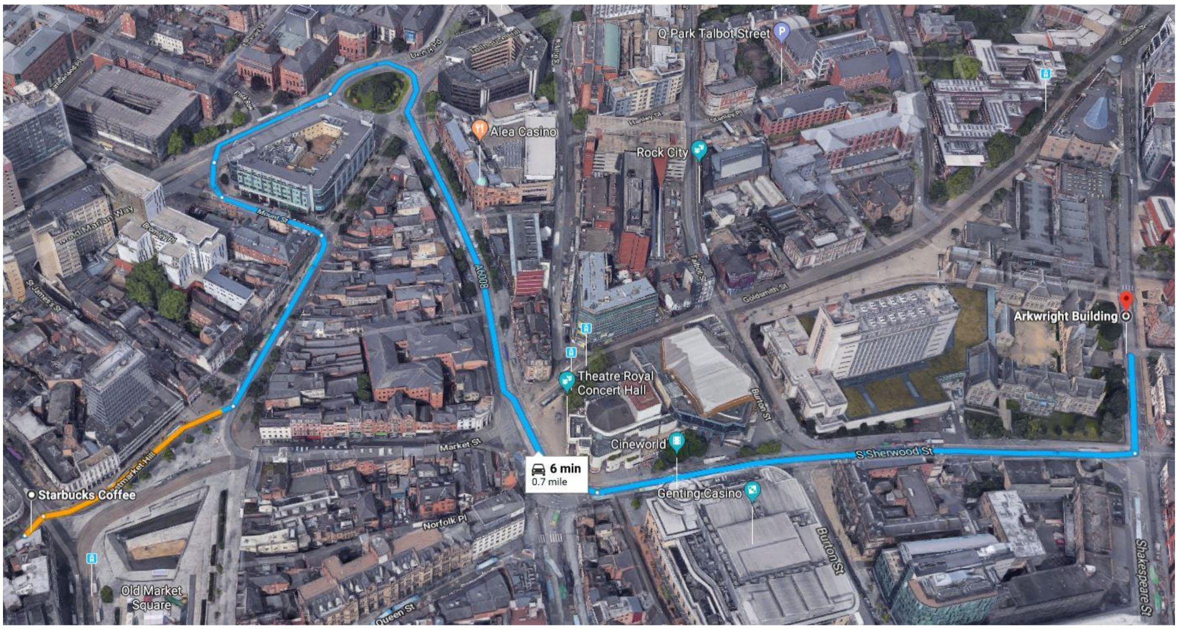


Figure 4-9. Proposed AV journey from Point A (Market Square; Starbucks) to Point B (Nottingham Trent University: Arkwright Building). (Google Maps, 2019).

4.4.2.1 Street design elements which will be *affected* by AV adoption

The first question in this section (Q11) asked the experts to examine the proposed route and select the street design elements issues they thought would be affected from a list, as follows:

- Zebra crossings
- On-street parking
- Off-street parking
- Load and go (User/Passenger drop-off and pick-up points)
- Traffic lights
- Road signs
- Road size (1 lane, 2 lanes or 3+ lanes)
- Road separation
- Roundabouts/intersections
- Islands

- Charging points
- One way streets / two way streets
- Restricted ways
- Other (*please specify*)

As per the results shown in Figure 4-10, according to the experts, most of these will be affected to a greater or lesser extent. Roundabouts and intersections, load and go points (drop-off/pick-up points), and zebra crossings were selected most often, with scores of 57.1%, 57.1% and 54.30%, respectively. By contrast, the experts expected off-street parking (25.70%) and islands (28.60%) to be least affected. 5.70% of experts selected the “Other” option and argued that infrastructure must necessarily change with the adoption of AVs.

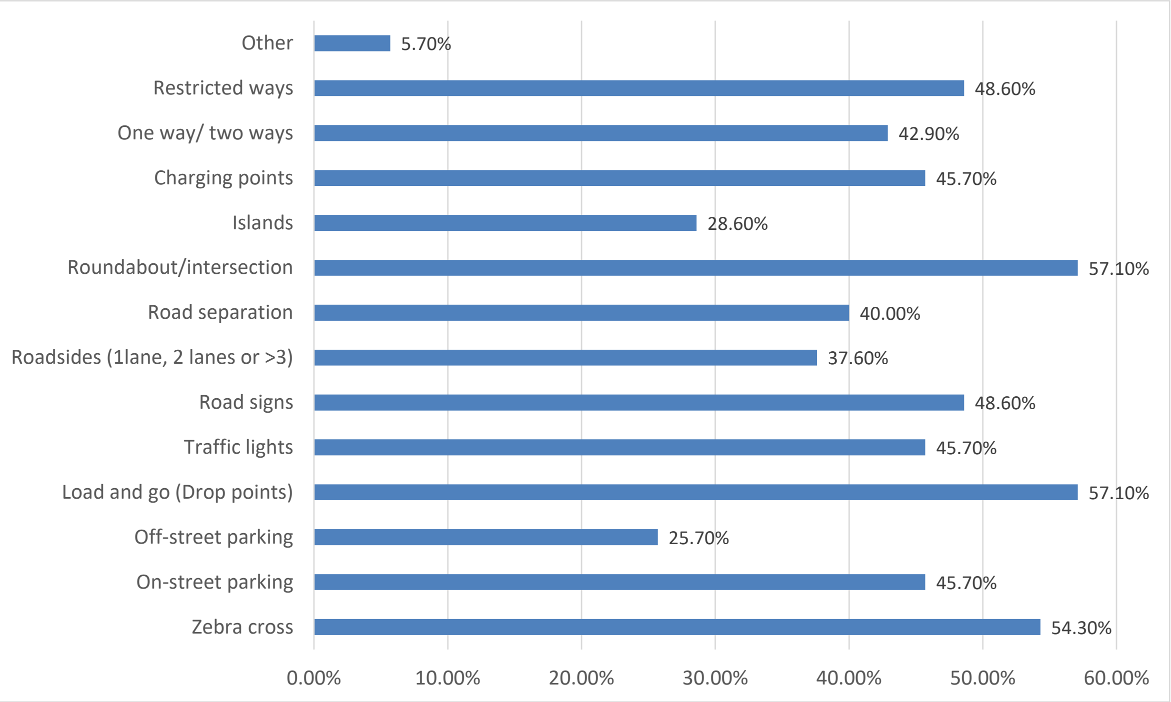


Figure 4-10. Q11: Considering the vehicle is fully autonomous, in your opinion, which of the following design principles and detailed design issues will be affected? (Author, 2021)

4.4.2.2 Street design elements which will be *removed* by AV adoption

The experts were then asked if they thought any of these elements would be removed by full AV adoption. As Figure 4-11 illustrates, on-street parking (43.8%), traffic light (40.6%) and road signs (46.9%) were selected most often. By contrast, zebra crossings (3.1%), road size (1 lane, 2 lanes or 3+ lanes) (6.3%) and one way/two ways streets (9.4%) were considered least likely to be removed. Nevertheless, 15.6% of experts believe that road signs will be removed entirely as they are the means of interactions between vehicles, and since cars will be autonomous, there is no need for them. In addition, while the experts accepted that AVs' advanced communication systems would mean they would not need many of these elements, they should remain in place because they have a significant impact on pedestrian behaviour.

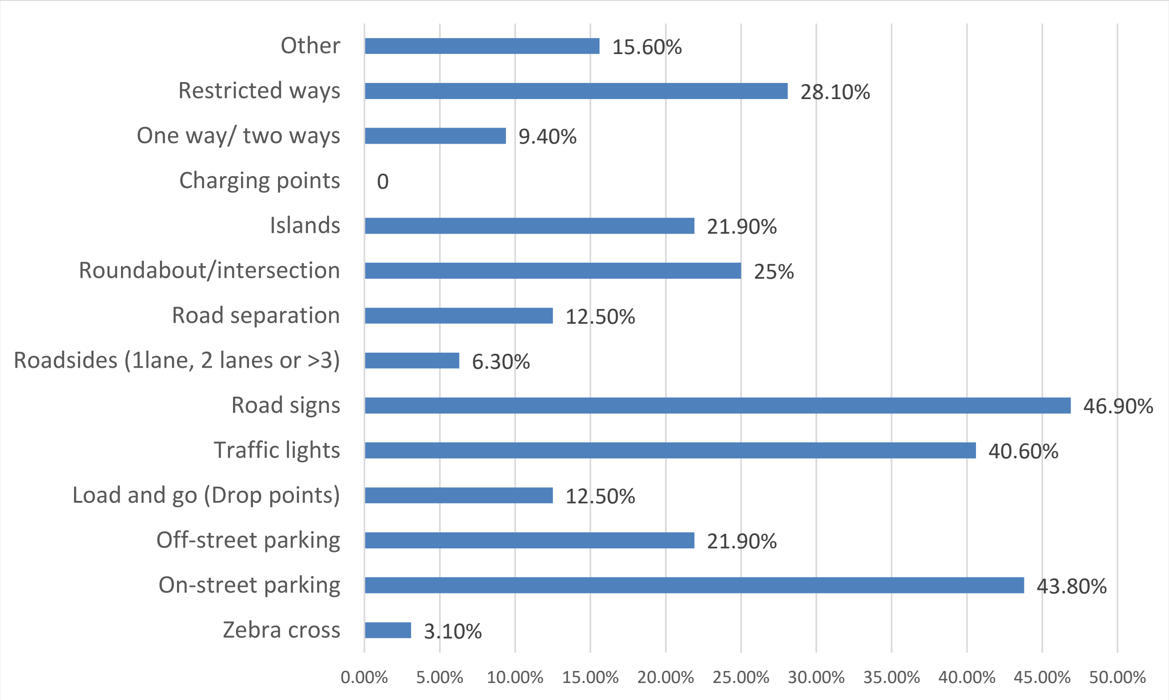


Figure 4-11. Q12: Considering the vehicle is fully autonomous, what do you think, which of the following design principles and detailed design issues will be removed?(Author, 2021)

4.4.2.3 Design guidance which will be affected by AV adoption

The experts were then asked to consider the MFS guidelines for design (MFS 1) an assess the extent to which certain design guidance would be affected using a four point scale (from extremely affected to not affected at all) with a fifth option if they were not sure. The design guidance items were those relating to: Layout and connectivity, Quality of place, Street users' needs, Street geometry, Parking, Traffic signs and markings, and Street furniture and lighting. The results are shown in Figure 4-12. As the figure illustrates, around 50% of the experts thought that layout and connectivity, parking, and traffic signs and markings would be extremely affected. By contrast, while most of the respondents thought that all the design guidance would be affected to some extent, a small proportion (3% - 6%) thought street users' needs, street geometry, and street furniture and lighting would not be affected at all.

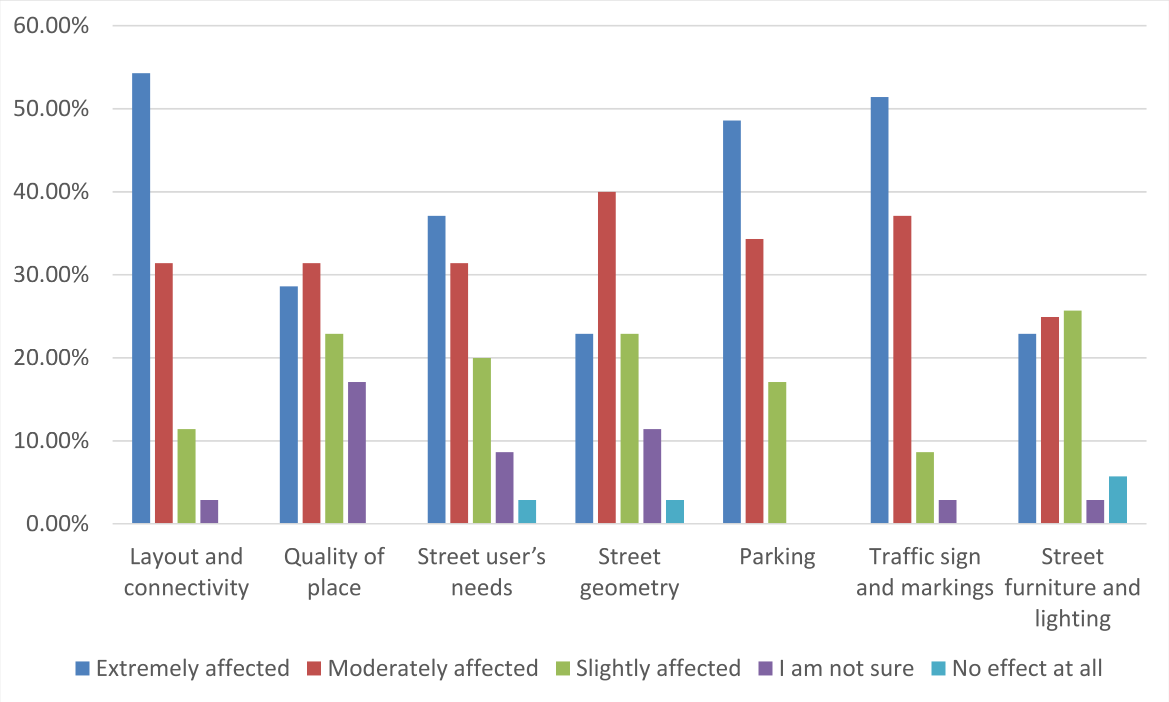


Figure 4-12. Q 13: Considering AVs fully autonomous level and the MFS guidelines for design, how much do you think the following design guidance will be affected? (Author, 2021)

4.4.2.4 AVs and the overall number of cars

The experts were then asked if they thought the adoption of AVs would increase or decrease the number of cars on the road, or have no real impact. An ‘Other’ option was also provided. The results are shown in Figure 4-13. Research suggests that growth in conventional car ownership will lead to around 6.2 billion trips being made in private vehicles in 2025, of which 50% will be urban trips, double the number of trips compared to 2005 (Soltani, 2017). However, more than 40% of the experts thought that the adoption of AVs would decrease vehicles ownership compared to 28% who thought it would increase. Roughly 20% expressed the view that AVs would have no effect. Any increase or decrease will depend on factors such as (a) the operation modes of AVs, (b) the cost (AVs may increase ownership if they are cheaper), (c) Shareability (ownership may decrease but the overall number of trips could increase), and (d) the combination transport modes (ownership may decrease if AVs are successfully combined with other modes, such as inner-city rail network).

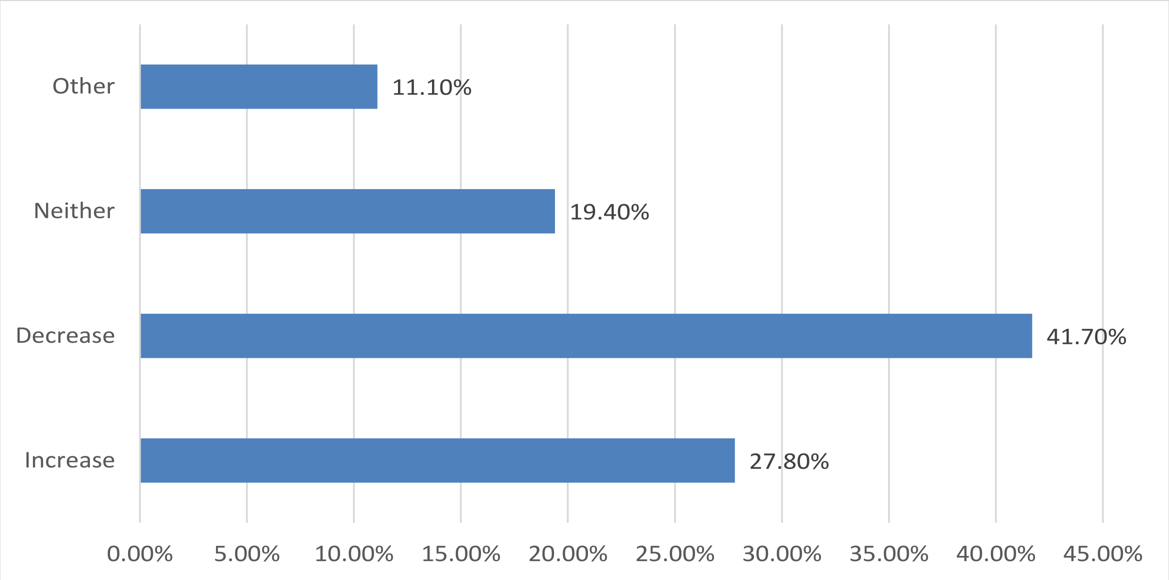


Figure 4-13. Q14: Do you think autonomous vehicles will affect the number of cars? (Author, 2021)

4.4.2.5 AVs and parking

Storage options for AVs

The next question asked respondents where they thought AVs should be stored when not in use (e.g. at night). A list of options was provided, and an 'Other' option was included. The responses are illustrated in Figure 4-14. These reveal a mixture of opinions amongst the experts: 37.10% believed that AVs should be stored in existing car parks in the city whereas 34.30% suggested creating underground/overground parking hubs, especially for AVs. Meanwhile, 20% thought that using the car parks of large supermarkets (such as Asda and Tesco) would be better. 8.60% of the experts mentioned other options or considerations, including: (a) the use of existing car parks depends on AVs' comprehensive programming and technology; (b) both new hubs and existing car parks should be considered; and (c) even if existing parking is used, new hubs should be created to cope with demand.

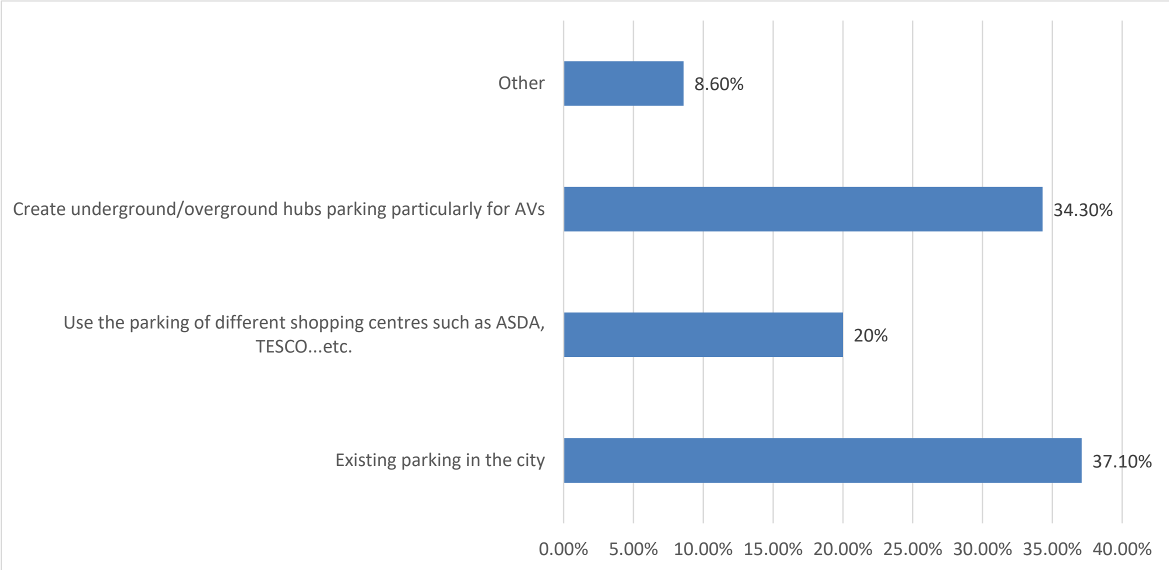


Figure 4-14. Q15: In the case where autonomous vehicles are not used, for instance, at night or at specific times, where do you think they should be stored? (Author, 2021)

Hub locations

In a follow-up question, experts were then asked about the optimal location of AV storage hubs (in the city centre, each neighbourhood, on the outskirts of the city) and provided with an option to suggest other alternatives. As Figure 4-15 shows, 61.10% of the experts thought that these hubs should be located in each neighbourhood compared to 19.40% who chose the city centre. Only 5.60% thought this type of parking should be on the outskirts. 13.90% of respondents provided alternative options. Some thought hubs should be distributed around different parts of the city, and locations suggested included: next to train stations, shopping centres, redundant brownfield sites, and other frequently used areas or those that have general parking restrictions.

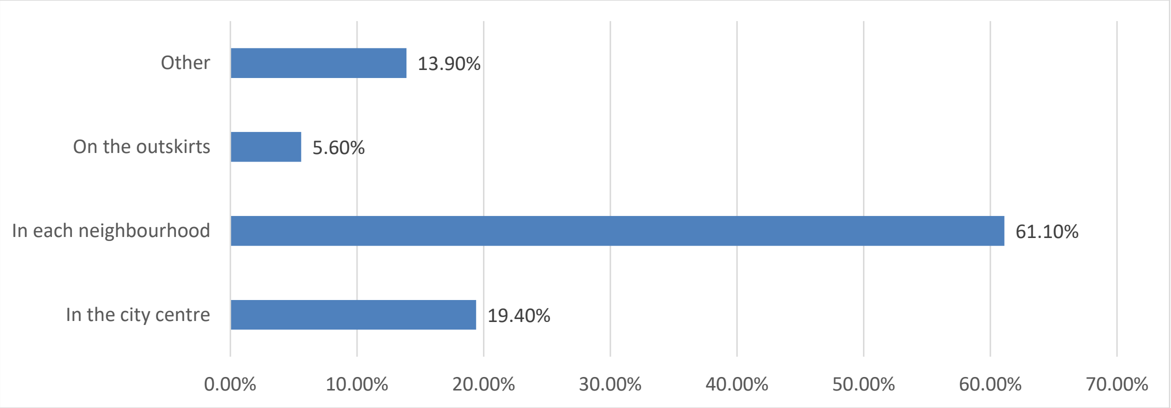


Figure 4-15. Q16: in case of creating specific parking (Hubs) for AVs, where do you think they should be located? (Author, 2021)

4.4.2.6 AV implementation phases and driving modes

The penultimate set of questions in this section asked experts about the phases of AV implementation. The first question asked them to select the areas where they thought AVs should be implemented first, and the second asked if they thought manual driving should be banned after the full adoption of AVs.

AV implementation phases

The experts were asked to select the locations for initial AV implementation from a list of five options: motorways (connecting cities), main roads (connecting different parts of the city), secondary roads, everywhere, or ‘Other’. The results are presented in Figure 4-16. As can be seen, implemented on the motorways was the most popular option (36.10%), with main roads and secondary roads tied on 25%. 11.10% of the participants concluded that they should be executed everywhere, with a holistic plan in place, through phased implementation and full public consultation.

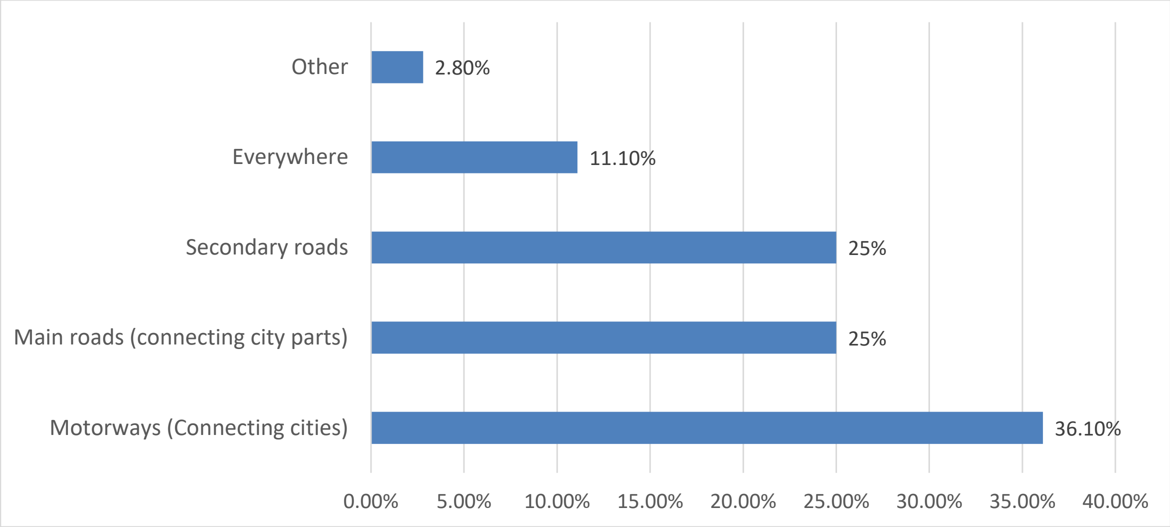


Figure 4-16. Q17: Where do you think autonomous vehicles (full automation) should be implemented first? (Author, 2021)

Driving modes

Experts were then asked if they thought manual driving should be banned once full AVs were running. An option to comment via an 'Other' option was also provided. As Figure 4-17 shows, 67% of experts thought manual driving should not be prohibited compared to 19% who were in favour of banning it. In terms of the comments made, some experts justified their objection to banning manual driving by saying it can be considered a vital option in an emergency. However, others believed that both modes should not be allowed together as this could create issues due to the lack of communication between them. Some participants suggested that manual driving may not be necessary for freight and commercial transport; hence it could be banned in these sectors.

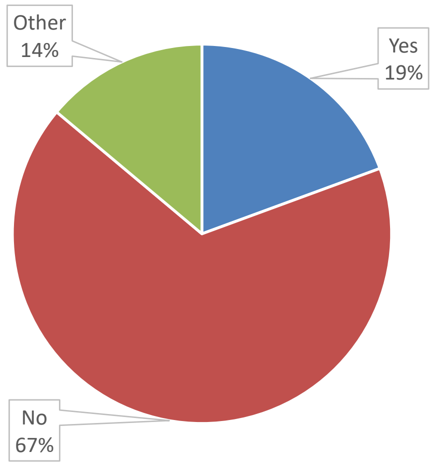


Figure 4-17. Q18: In the future, after the full adoption of Autonomous vehicles, do you think manual driving should be banned?(Author, 2021)

4.5 Hypotheses Testing and Analysis

4.5.1 Hypothesis 1

Hypothesis 1 (See Table 4-8) was designed to establish whether the experts were biased in their assessment of the proposed barriers due to their areas of expertise. Specifically, it studied whether their specialisation affected their rating and ranking of the barriers. This also helped to identify the relationship between discipline and barrier, which in turn helped to identify which obstacles should be prioritised.

Table 4-8. Hypothesis 1 (Author, 2021)

Hypothesis 1	**Questions 1 & 6**
	a. Experts *rate* the importance of the barriers based on their area of expertise (Q1: area of expertise).
To study the relationship between experts' rating and ranking of the AV barriers and their fields of expertise	**Questions 1 & 7** **b.** Experts *rank* the importance of the barriers based on their area of expertise (Q1: area of expertise).

4.5.1.1 Hypothesis 1.1

The analysis of Hypothesis 1.1 was broken into seven parts based on the seven barriers themselves. Each obstacle (Data processing, Safety, Affordable sensors, Communication, Accurate positioning and mapping, User acceptance and reaction, and Ethics) is analysed separately below.

Data processing

The results shown in Table 4-9 demonstrate the absence of a significant statistical link between area of expertise and data processing as a barrier to AV adoption (association P-value> 0.05). Data processing was seen as extremely important by 83.3% of experts in Transportation / Manufacturing, and a substantial portion of the Planning / Environment experts thought it was either extremely important (43.8%) or very important (31.3%). Meanwhile, around 25% of Planning / Environment experts thought it was only moderately or slightly important. On the other hand, a majority of the experts in the Technology (62.5%) and Users and Others (66.7%) categories believed data processing is extremely important.

Table 4-9. Cross-tabulation between areas of expertise and importance of data processing (perception) as a barrier (Author, 2021).

		Areas of expertise			
		Planning/ Environment	**Technology**	**Transportation/ Manufacturing**	**Users and Others**
Data processing (Computer software and hardware)	**Extremely important**	43.8% (7)	62.5% (5)	83.3% (5)	66.7%(4)
	Moderately Important	18.8% (3)	0.0% (0)	0.0% (0)	33.3% (2)
	Slightly Important	6.3% (1)	12.5% (1)	0.0% (0)	0.0% (0)
	Very Important	31.3% (5)	25.0% (2)	16.7% (1)	0.0% (0)
P-value (Chi-square independence test)		**0,530^{NS} *(df=09)***			

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the column variable and the row variable at P≤ 0.05.

a. Safety

Regarding safety, there was clear agreement between the experts on the importance of this barrier regardless of their areas of expertise. From a statistical point of view, the experts' responses are independent of their area of expertise (P-value of association> 0.05). In other words, the type of expertise did not influence the rating of the importance degree of the safety barrier. For instance, experts from Technology, Transportation / Manufacturing and Users and Others agreed fully (100%) that safety is extremely important (See Table 4-10).

Table 4-10. Cross-tabulation between areas of expertise and importance of safety as a barrier (Author, 2021)

		Areas of expertise			
		Planning/ Environment	**Technology**	**Transportation/ Manufacturing**	**Users and Others**
Safety	**Extremely important**	93.8% (15)	100.0% (8)	100.0% (6)	100.0% (6)
	Very Important	06.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)
P-value (Chi-square independence test)		**0.999^{NS} *(df=03)***			

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the column variable and the row variable at P≤ 0.05.

b. Affordable sensors

Table 4-11 shows that affordable sensors were viewed as extremely important by 83.3% of experts in the "Users and Others" category, while they were seen as very important by 50% of experts in Transportation / Manufacturing and as moderately important by the rest (50%). On the other hand, the Technology specialists and the Planning / Environment experts disagreed on the importance degree of this barrier, and 12.5% of the Planning/Environment experts thought it should be removed from the study. Overall, statistically, the experts' assessment of this barrier's degree importance is independent of their speciality (P-value of association> 0.05).

Table 4-11. Cross-tabulation between areas of expertise and importance of affordable sensors (Author, 2021).

		Areas of expertise			
		Planning/ Environment	**Technology**	**Transportation/ Manufacturing**	**Users and Others**
	Extremely important	18.8% (3)	25.0% (2)	0.0% (0)	83.3% (5)

Affordable Sensors	**Very Important**	31.3% (5)	12.5% (1)	50.0% (3)	0.0% (0)
	Slightly Important	12.5% (2)	37.5% (3)	0.0% (0)	0.0%(0)
	Moderately Important	12.5% (2)	25.0% (2)	50.0% (3)	16.7% (1)
	Not Important at all	12.5% (2)	0.0% (0)	0.0% (0)	0.0% (0)
	Remove this category	12.5% (2)	0.0% (0)	0.0% (0)	0.0% (0)
P-value (Chi-square independence test)		**0.076**^{NS} ***(df=15)***			

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the column variable and the row variable at P≤ 0.05.

c. Communication

Regarding communication, more than half of the Planning / Environment experts (56.3%), and more than 60% of the Technology experts thought this barrier was moderately important. However, it was considered to be extremely important by experts in Transportation / Manufacturing (66.7%) and by half of the "Users and Others" experts (See Table 4-12). Similar to the previous barriers, statistically, the importance of this barrier was also independent of the area of expertise (P-value of association> 0.05).

Table 4-12. Cross-tabulation between area of expertise and importance of communication as a barrier (Author, 2021)

		Areas of expertise			
		Planning/ Environment	**Technology**	**Transportation/ Manufacturing**	**Users and Others**
Communication	**Extremely important**	18.8% (3)	25.0% (2)	0.0% (0)	83.3% (5)
	Very Important	31.3% (5)	12.5% (1)	50.0% (3)	0.0% (0)
	Slightly Important	12.5% (2)	37.5% (3)	0.0% (0)	0.0%(0)
	Moderately Important	12.5% (2)	25.0% (2)	50.0% (3)	16.7% (1)
	Not Important at all	12.5% (2)	0.0% (0)	0.0% (0)	0.0% (0)
	Remove this category	12.5% (2)	0.0% (0)	0.0% (0)	0.0% (0)
P-value (Chi-square independence test)		**0.490**^{NS} ***(df=09)***			

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the column variable and the row variable at P≤ 0.05.

d. Accurate positioning and mapping

As Table 4-13 illustrates, 100% of the "Users and Others" experts found accurate positioning and mapping barrier extremely important. Similarly, a large part (68.8%) of the experts in the Planning / Environment field shared the same thought. In 50% of cases, the Technology experts saw accurate positioning and mapping as very important, as did half of the of Transportation / Manufacturing experts (50%). Statistically, the importance of this barrier is also independent of the area of expertise (P-value of association> 0.05).

Table 4-13. Cross-tabulation between areas of expertise and importance of accurate positioning and mapping (Author, 2021).

		Areas of expertise			
		Planning/ Environment	**Technology**	**Transportation/ Manufacturing**	**Users and Others**
Accurate positioning and mapping	**Extremely Important**	68.8% (11)	25.0% (2)	33.3% (2)	100.0% (6)
	Very Important	18.8% (3)	50.0% (4)	50.0% (3)	0.0% (0)
	Moderately Important	6.3% (1)	12.5% (1)	16.7% (1)	0.0% (0)
	Slightly Important	6.3% (1)	12.5(1)	0.0% (0)	0.0% (0)
P-value (Chi-square independence test)		**0.117^{NS} *(df=09)***			

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the column variable and the row variable at P≤ 0.05.

e. User acceptance and reaction

User acceptance and reaction seemed to be regarded as a significant barrier by the experts regardless of their areas of expertise (See Table 4-14). 50% of the Planning / Environment experts considered it to be very important, compared to 31.30% who found it extremely important. This was similar to the Technology experts: 50% of them thought this barrier was very important, with 37.5% considering it extremely important. 33.3% of the experts in both "Transportation/ Manufacturing" and "Users and Others" rated this barrier very important.

Interestingly 12.5% of Technology experts and 16.7% of Transportation/ Manufacturing experts thought this barrier was not important at all. Again statistically, user acceptance and reaction is also independent of the area of expertise (P-value of association> 0.05).

Table 4-14. Cross-tabulation between areas of expertise and importance of user acceptance and reaction (Author, 2021).

		Areas of expertise			
		Planning/ Environment	**Technology**	**Transportation/ Manufacturing**	**Users and Others**
User acceptance and reaction	**Extremely Important**	31.3% (5)	37.5% (3)	33.3% (2)	50.0% (3)
	Very Important	50.0% (8)	50.0% (4)	33.3% (2)	33.3% (2)
	Moderately Important	12.5% (2)	0.0% (0)	16.7% (1)	16.7% (1)
	Slightly Important	6.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)
	Not important at all	0.0% (0)	12.5% (1)	16.7% (1)	0.0% (0)
P-value (Chi-square independence test)		**0.889**^{NS} ***(df=12)***			

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the column variable and the row variable at P≤ 0.05.

f. Ethics

As Table 4-15 demonstrates, the degree of importance given to this barrier was totally independent of the area of expertise (P-value of association> 0.05). Overall, between 25% and 50% of the experts in each category rated it as either "extremely important" or "very important". However, 6.3% of the planning /environment experts thought it was better to remove this barrier.

Table 4-15. Cross-tabulation between areas of expertise and importance of ethics (Author, 2021).

		Areas of expertise			
		Planning/ Environment	**Technology**	**Transportation/ Manufacturing**	**Users and Others**
Ethics	**Extremely Important**	50.0% (8)	37.5% (3)	33.3% (2)	50.0% (3)
	Very Important	25.0% (4)	37.5% (3)	33.3% (2)	33.3% (2)
	Moderately Important	12.5 (2)	12.5% (1)	16.7% (1)	16.7%(1)
	Slightly Important	6.3% (1)	12.5 (1)	16.7% (1)	0.0% (0)

	Remove this category	6.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)
P-value (Chi-square independence test)		**0.999**^{NS} ***(df=12)***			

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the column variable and the row variable at P≤ 0.05.

In conclusion, analysis of the results obtained in respect of Hypothesis 1.1 proved that the respondents' fields of expertise did not seem to affect their views of the importance of the barriers they rated. Therefore, we reject the hypothesis "*Experts rate the importance of the barrier based on their area of expertise*".

4.5.1.2 Hypothesis 1.2

Similar to Hypothesis 1.1, Hypothesis 1.2 was used to analyse the relationship between area of expertise and the ranking of the barriers based on their importance. The hypothesis to be tested was: "*Experts rank the importance of the barriers based on their area of expertise".*

The results relating to the "Relative Importance Index (RII)" illustrated in Table 4-16 and Figure 4-18 show that safety was ranked first by all the experts, regardless of their areas of expertise. All the experts ranked data processing (computer software and hardware) second, with the exception of those in the field of technology; they saw ethics as the most important obstacle after the safety. Overall, accurate positioning and mapping was ranked third by most experts, apart from those in the "Users and Others" category who ranked it fourth; they ranked affordable sensors third. Planning/environment and technology specialists gave equal importance to communication and accurate positioning and mapping.

At the lower end of the rankings, communication was ranked fifth by technologists and 'Users and others'. Technologists also gave affordable sensors a low ranking (7^{th}), while experts in other fields gave less importance to user acceptance and reaction and ethics. The comparison between the ranking ascribed to each barriers and the experts' fields of expertise did not show a statistically significant difference.

Table 4-16. Ranking of importance of barriers in relation to area of expertise (Author, 2021).

		Areas of expertise				**Global Relative Importance Index**	***P-value (Kruskal Wallis Anova test)***
		Planning/ Environment	**Technology**	**Transportation / Manufacturing**	**Users and Others**		
Ranking of Importance of Barriers	Data processing (Computer software and hardware)	0.63 **(2)**	0.54 **(4)**	0.60 **(2)**	0.67 **(2)**	0.64**(2)**	**0.894^{NS} (df=3)**
	Safety	0.91 **(1)**	1.00 **(1)**	1.00 **(1)**	1.00 **(1)**	0.96 **(1)**	**0.102^{NS}(df=3)**
	Affordable sensors	0.51 **(4)**	0.38 **(7)**	0.43 **(5)**	0.64 **(3)**	0.44 **(6)**	**0.087^{NS} (df=3)**
	Communication	0.57 **(3)**	0.43 **(5)**	0.52 **(3)**	0.45 **(5)**	0.50 **(4)**	**0.950^{NS} (df=3)**
	Accurate positioning and mapping	0.57 **(3)**	0.61 **(3)**	0.52 **(3)**	0.52 **(4)**	0.58 **(3)**	**0.553^{NS} (df=3)**
	User acceptance and reaction	0.46 **(6)**	0.39 **(6)**	0.50 **(4)**	0.36 **(6)**	0.42 **(7)**	**0.488^{NS} (df=3)**
	Ethics	0.48 **(5)**	0.80 **(2)**	0.43 **(5)**	0.36 **(6)**	0.46 **(5)**	**0.669^{NS} (df=3)**

The value in parentheses represents the rank of “Importance of the barrier” for the same area of expertise. NS: the difference is statistically insignificant between the colon variables for the same row variable at P≤ 0.05. df= degrees of freedom.

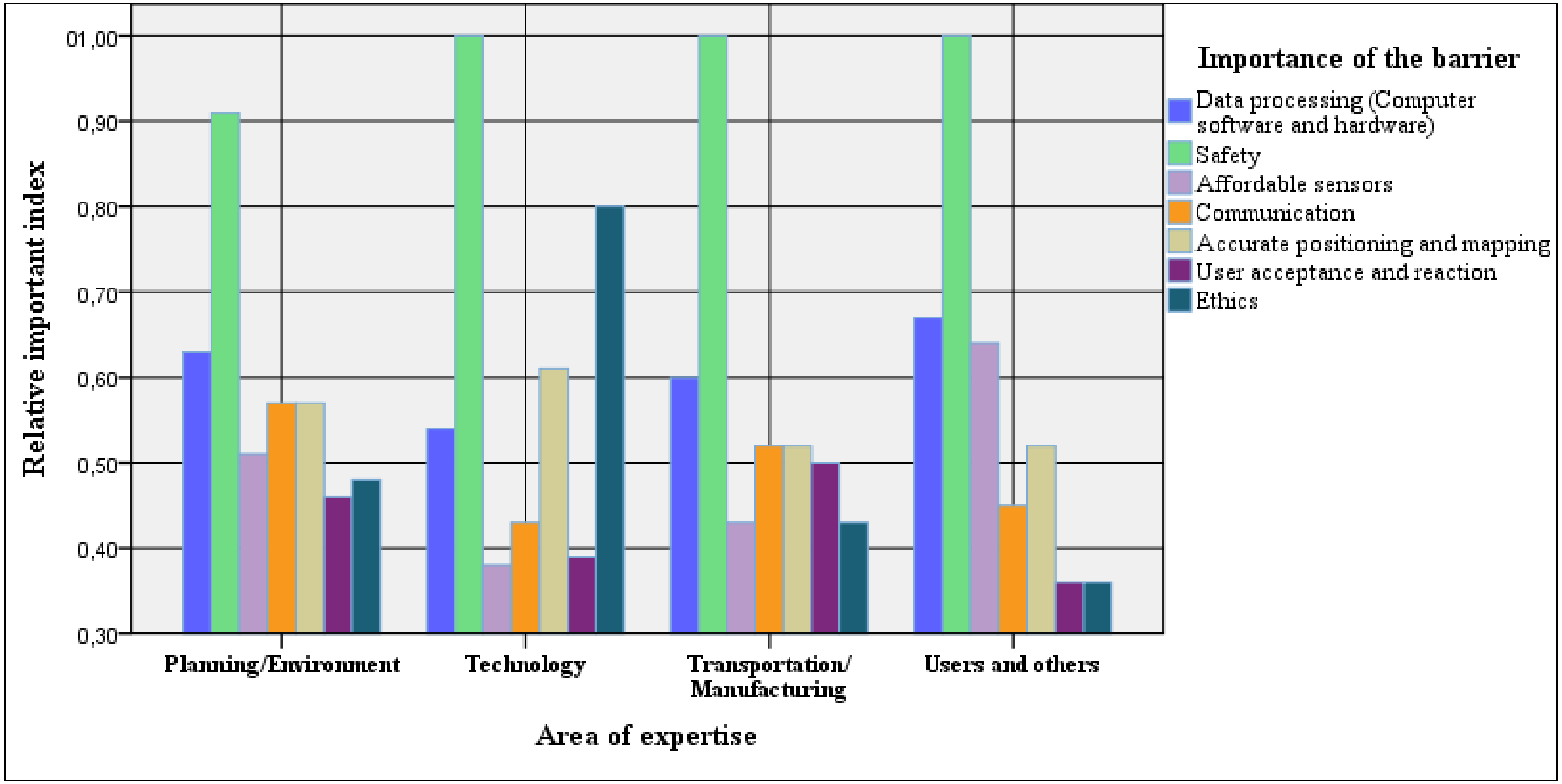


Figure 4-18. Relative importance index of the barriers by area of expertise (Author, 2021).

The analysis of hypothesis 1.2 demonstrated that the experts' area of expertise did not influence their ranking of the barriers. The "RII" is statistically insignificant. The P-value results for all the seven obstacles range between 0.087^{NS} (df=3) and 0.950^{NS} (df=3) ($P \leq 0.05$). Therefore, we reject the hypothesis that "*Experts rank the importance of the barriers based on their area of expertise*". However, the Global Relative Importance Index results (shown in Table 4-16) validate the ranking of the barriers identified in "4.4.1.2 Framework evaluation" as follows:

1. Safety
2. Data processing (Computer software and hardware)
3. Accurate positioning and mapping
4. V2X communication
5. Users acceptance and behaviour
6. Ethics
7. Affordable sensors

4.5.2 Hypothesis 2

Hypothesis 2 considered whether the experts' answers about the substance of the proposed framework were consistent with their suggestions about the need to investigate other barriers. It examined the responses to Question 5: "*Does this Framework show too many, too few, or about the right number of barriers and vehicle specifications?*" and Question 8: "*Do you think there are more barriers and vehicle specifications to be investigated, either with a direct or indirect effect*?" The structure of this hypothesis is shown in Table 4-17.

Table 4-17. Hypothesis 2 (Author, 2021)

Hypothesis 2	**Questions 5 & 8**
To study the relationship between the experts' opinions about the substance of the proposed framework	**a.** Experts who expressed the view that the proposed framework has the right number of barriers will not suggest investigating further obstacles. **b.** Experts who expressed the view that the proposed framework has a small number of barriers will suggest investigating further obstacles.

and whether they suggest other barriers need to be investigated

Examination of the possible association between the opinion of the experts on the substance of the proposed framework and their responses about investigating further obstacles showed that 47.1% of the experts who agreed that the proposed framework has the right number of barriers suggested investigating additional obstacles. Similarly, 52.9% of those who were "not sure" were advised to investigate further. Meanwhile, 80% of the experts who thought the framework contained "slightly too few" barriers and specifications recommended exploring more. The statistical dependence between these two variables is insignificant (P-value is 0,141NS > 0.05), as shown in Table 4-18. Hence, we reject Hypothesis 2.

Table 4-18. Cross-tabulation between the substance of the proposed framework and investigating further obstacles (Author, 2021).

		Substance of the proposed framework					
		Right number	**Much too many**	**Slight too many**	**Slightly too few**	**Somewhat too few**	**Somewhat too many**
Investigating further obstacles	**Yes**	47.1% (8)	0.0% (0)	33.3% (1)	80.0% (8)	0.0% (0)	50.0% (2)
	No	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	25.0% (1)
	I am not sure	52.9% (9)	100.0%(1)	66.7% (2)	20.0% (2)	100.0% (1)	25.0% (1)
P-value (independence test)		**0,141^{NS} *(df=10)***					

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the colon variable and the row variable at P≤ 0.05.

4.5.3 Hypothesis 3

Hypothesis 3 was intended to explore whether there was a relationship between the experts' assessment of the substance of the proposed framework, their recommendations for further investigation of AV barriers and vehicle specifications, and their expectations about the time period required for full AVs to start operating on our roads. The structure of this hypothesis is shown in Table 4-19.

Table 4-19. Hypothesis 3 (Author, 2021)

Hypothesis 3	**Questions 5 & 9**
To study the relationship between the experts' opinions about whether further investigation of AV barriers was required and their expectations about the time frame for full AV implementation.	**a.** Experts who agreed that more barriers needed to be investigated, anticipate that full AVs will be ready in 11-15 years, 16-29 years, or after 30 years. **b.** Experts who said no more barriers needed to be investigated, anticipate that full AVs will be ready in 0-5 years or 6-10 years. **c.** Experts who said that they are not sure whether there is a need to investigate other barriers anticipate that full AVs will be ready after 30 years.

In order to analyse Hypothesis 3, it was first useful to look at the cross-tabulation between the experts' opinion about the number of barriers and specifications included in the proposed framework (substance of the framework) and their expectations about the time required to have full AVs on our roads. This is shown in Table 4-20.

The experts' opinion on the substance of the proposed framework is independent of their opinion on the expected time to have full AVs operating on our roads. In general, few experts think full AVs will be running on our roads in the next five years; however, 66.7% of the experts who thought the proposed framework contained slightly too much selected this time frame. By contrast, 75% of those who thought it contained somewhat too many, believed that a period of 6 - 10 years was realistic. However, the experts who said the framework had about the right number of barriers did not have a common opinion on the period required. The statistical association between time expectations for full AVs and the substance of the proposed framework is not significant (P-value> 0.05). However, based on the responses in each time category, the most common time expectation is between 6 - 10 years.

Table 4-20. Cross-tabulation between framework substance and expected time for AVs to be fully operational (Author, 2021).

		The substance of the proposed framework					
		Right number	**Much too many**	**Slight too many**	**Slightly too few**	**Somewhat too few**	**Somewhat too many**
Expected time for AVs to be fully operational	**0-5 Years**	11.8% (2)	0.0% (0)	66.7% (2)	10.0% (1)	0.0%(0)	0.0% (0)
	6-10 Years	23.5% (4)	0.0% (0)	0.0% (0)	30.0% (3)	100.0% (1)	75.0% (3)
	11-15 Years	23.5% (4)	0.0% (0)	0.0% (0)	20.0% (2)	0.0% (0)	0.0% (0)
	16-29 Years	23.5% (4)	0.0% (0)	33.3% (1)	30.0% (3)	0.0% (0)	0.0% (0)
	After 30 years	17.6% (3)	100.0% (1)	0.0% (0)	0.0% (0)	0.0% (0)	25.0% (1)
	Other	0.0% (0)	0.0% (0)	0.0% (0)	10.0% (1)	0.0% (0)	0.0% (0)
P-value (independence test)		**0.403^{NS}** ***(df=25)***					

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the colon variable and the row variable at P≤ 0.05.

The opinion of the experts about investigating further obstacles is also independent of their views about the expected time period for full AV operation. In purely descriptive terms, only 10.5% of the experts who thought more barriers needed to be investigated forecast that full AVs would operating on our roads in a period of 0 - 5 Years. This was also the case for 18.8% of those experts who were not sure if further investigation was needed. The possibility of having full AVs operating on our roads after 6 - 10 years was supported by 31.6% of those experts who suggested more barriers should be investigated and by 25.0% of those who were not sure about this (See Table 4-21).

Table 4-21. Cross-tabulation between investigating further obstacles and expected time for AVs to be fully operational (Author, 2021).

		Investigating further obstacles		
		Yes	**No**	**I am not sure**
Expected time for AVs to be fully operational	**0-5 Years**	10.5% (2)	0.0% (0)	18.8% (3)
	6-10 Years	31.6% (6)	100.0% (1)	25.0% (4)
	11-15 Years	26.3% (5)	0.0% (0)	6.3% (1)
	16-29 Years	21.1% (4)	0.0% (0)	25.0% (4)

	After 30 years	5.3% (1)	0.0% (0)	25.0% (4)
	Other	5.3% (1)	0.0% (0)	0.0% (0)
P-value (independence test)		**0.467**[NS] ***(df=25)***		

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the colon variable is the row variable at P≤ 0.05.

The statistical association between the time required for full AV operation and investigating further obstacles is not significant (P-value> 0.05). Nevertheless, as per the number of expert answers, 6-10 years is seen as the expected time for AVs to be fully operational.

4.5.4 Hypothesis 4

This hypothesis looks at the relationship between the experts' area of expertise and their views on which of the three domains suggested (City Planning, Regulations or Vehicle Manufacturing) should be developed first. The structure of this hypothesis is shown in *Table 4-22*.

Table 4-22. Hypothesis 4 (Author, 2021)

Hypothesis 4	**Questions 1 & 10**
To analyse the relationship between the experts' areas of expertise and their opinion about which domain needs to be developed first.	The majority of experts (all areas of expertise) are likely to think that the "Vehicle Manufacturing" domain should be developed first.

As Table 4-23 illustrates, there is no statistically significant relationship, which means that the choice of domain is independent of the areas of expertise (P- value> 0.05). A majority of the experts think that city planning and regulations must be developed before vehicle manufacturing. City planning was selected by 43.8% of the Planning/Environment experts, 50% of those in the Transportation / Manufacturing field, and 66.7% of Users and Others. "Vehicle manufacturing" was selected by just five experts out of a total of 36 (13.89%).

Therefore, we reject the hypothesis "*The majority of experts (across all areas of expertise) are likely to think that the "Vehicle Manufacturing" domain should be developed first*".

Table 4-23. Cross-tabulation between areas of expertise and domains which should be prioritised for development (Author, 2021).

		Areas of expertise			
		Planning / Environment	**Technology**	**Transportation / Manufacturing**	**Users and Others**
Domain needed to be developed first	**City Planning**	43.8% (7)	37.5% (3)	50.0% (3)	66.7% (4)
	Regulations	37.5% (6)	37.5% (3)	50.0% (3)	16.7% (1)
	Vehicle Manufacturing	12.5% (2)	25.0% (2)	0.0% (0)	16.7% (1)
	Other	6.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)
P-value (independence test)			**0.929^{NS}** ***(df=25)***		

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the colon variable and the row variable at $P \leq 0.05$.

4.5.5 Hypothesis 5

This hypothesis analyses the relationship between the experts' opinions about the design principles and issues that are expected to be affected by AV implementation and those which are expected to be removed or eliminated in the future. The structure of this hypothesis is shown in Table 4-24.

Table 4-24. Hypothesis 5 (Author, 2021)

Hypothesis 5	**Questions 11 & 12**
To analyse the relationship between the design principles and design issues which will be affected and those which will be removed .	**a.** Design principles and design issues which were identified as being affected by AV implementation will be removed. (To see whether the design principles and design issues being affected will be removed in the future, “transition”)

As Table 4-25 demonstrates, in terms of the design principles and issues that will be *affected* by AV adoption, the experts indicated that they thought roundabouts/intersections, zebra crossings and load and go (Drop-off/pick-up) points would be most likely to be affected.

58.3% of the experts surveyed (21 out of 36) believe that roundabouts/intersections will be affected, with 55.6% selecting zebra crossings and the same proportion choosing load and go points. By contrast, off-street parking was considered least likely to be affected (25%).

Table 4-25. Experts' responses regarding the design principles and issues will be affected by AV adoption (Author, 2021).

		Multiples Responses		% of Experts
		No.	**%**	
Design principles and issues which will be *affected*	**Roundabout/intersection**	21	10.0%	58.3%
	Zebra crossings	20	9.5%	55.6%
	Load and go (Drop points)	20	9.5%	55.6%
	Road signs	18	8.5%	50.0%
	Restricted ways	18	8.5%	50.0%
	On-street parking	17	8.1%	47.2%
	Traffic lights	17	8.1%	47.2%
	Charging points	16	7.6%	44.4%
	One way/ two ways	15	7.1%	41.7%
	Roadsides (1 lane, 2 lanes or 3+)	14	6.6%	38.9%
	Road separation	14	6.6%	38.9%
	Islands	10	4.7%	27.8%
	Off-street parking	9	4.3%	25.0%
	Other	2	0.9%	5.6%
Total		211	100.0%	-

Figure 4-19 ranks the elements according to the number of experts who thought they were likely to be affected by AV adoption. The top seven elements were identified as follows:

- Roundabouts/Intersections
- Load and go (Drop points)
- Zebra cross
- Road signs
- Restricted ways
- On-street parking
- Traffic lights

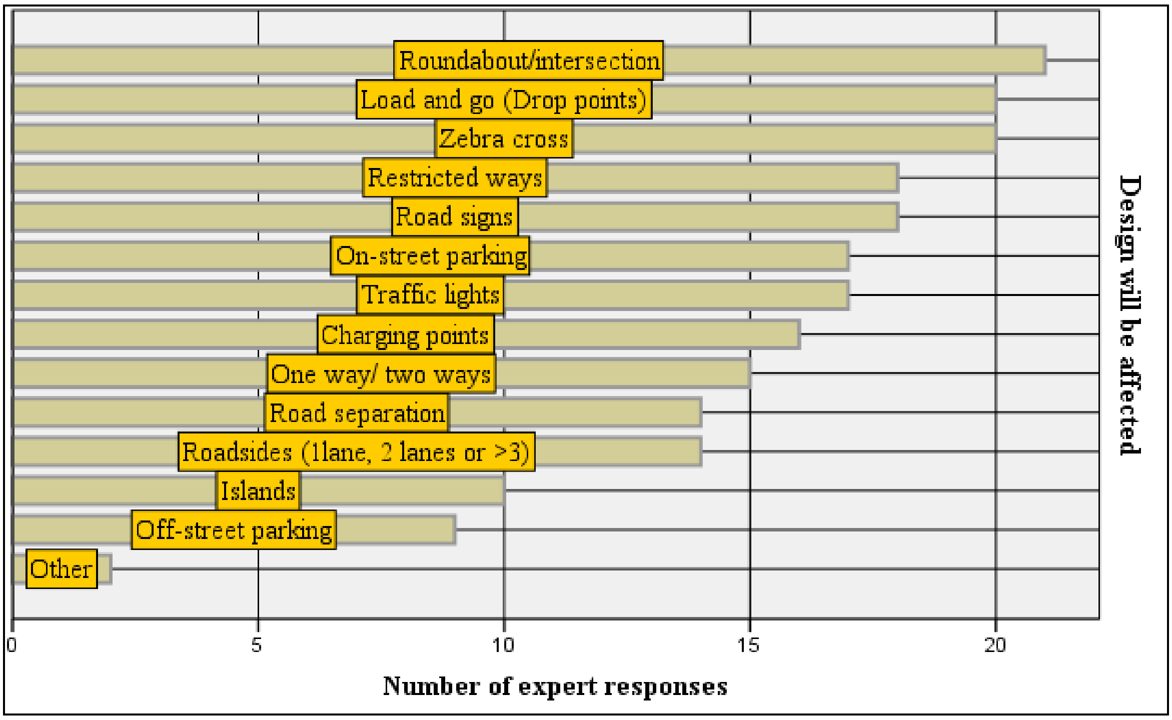


Figure 4-19. Rank of design principles and detailed design issues which will be affected by AV adoption (Author, 2021).

The second part of this hypothesis involved analysing the experts' views about which elements they expected to be removed when AVs are fully operational. As Table 4-26 shows, the elements selected most frequently were road signs (almost 47%), off-street parking (43.8%) and traffic lights (40.6%). The item that were seen as least likely to be removed were islands, zebra crossings, road signs, and one way / two way streets. No experts thought charging points would be removed from city planning for AVs.

Table 4-26. Experts' responses about design principles and design issues which will be removed as a result of AV adoption (Author, 2021).

		Multiples Responses		% of Experts
		No.	**%**	
Design principles and design issues which will	**Road signs**	15	16.3%	46.9%
	On-street parking	14	15.2%	43.8%
	Traffic lights	13	14.1%	40.6%
	Restricted ways	9	9.8%	28.1%
	Roundabout/intersection	8	8.7%	25.0%
	Off-street parking	7	7.6%	21.9%

	Other	5	5.4%	15.6%
	Load and go (Drop points)	4	4.3%	12.5%
	Road separation	4	4.3%	12.5%
	One way/ two ways	3	3.3%	9.4%
	Roadsides (1 lane, 2 lanes or 3+)	2	2.2%	6.3%
	Zebra cross	1	1.1%	3.1%
	Islands	1	1.1%	3.1%
	Charging points	0	0%	0%
Total		92	100.0%	-

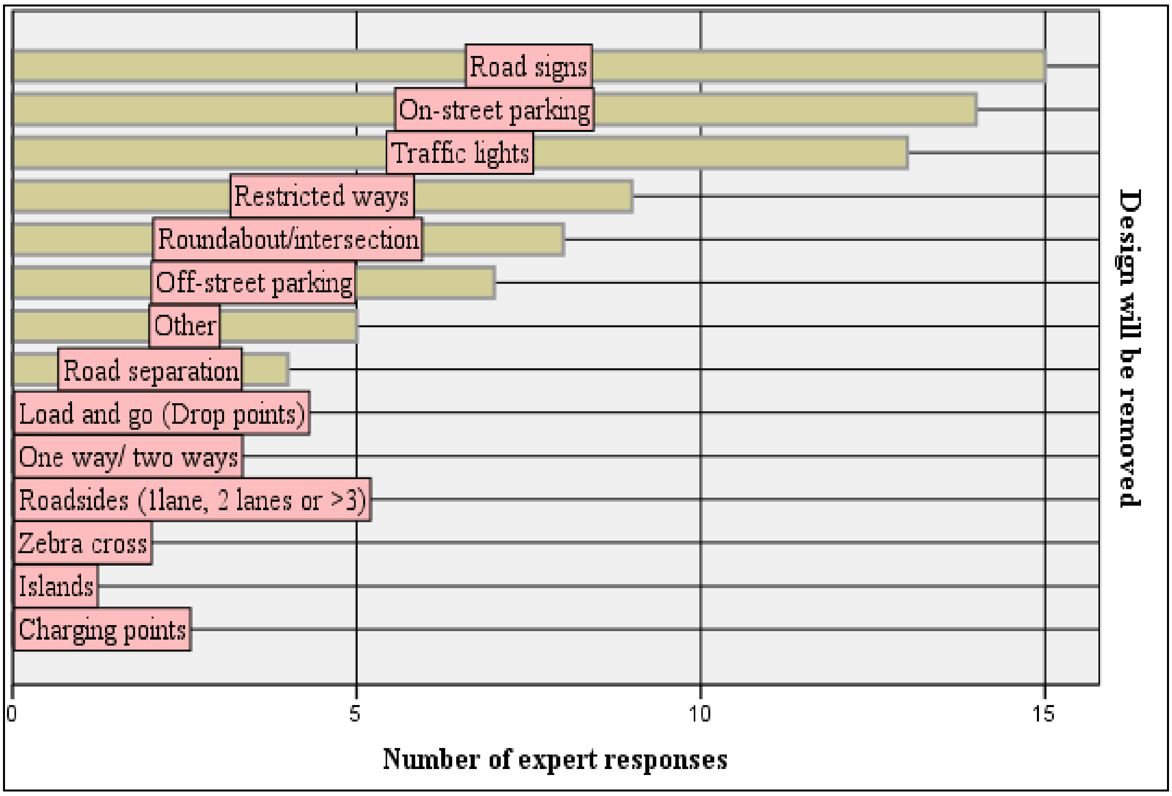


Figure 4-20. Ranking of the design principles and design issues which will be removed as a result of AV adoption (Author, 2021).

The cross-analysis of the experts' responses regarding the elements that will be affected and those that will be removed by AV adoption is shown in Table 4-27. This clearly demonstrates a divergence in the experts' forecasts. Examining the responses with high frequencies (more than 50%), it seems that 50% of the experts who predict that on-street parking will be affected also think it will be removed. The range of views is most visible in respect of road signs: 87.5% of those who think off-street parking will be affected think road signs will be eliminated, a view shared by 75% of the experts who think traffic islands will be affected, while just 50% of those who think road separation will be affected hold this view.

Table 4-27. Cross-tabulation of experts' responses regarding design principles and design issues which will be affected and those which will be removed (Author, 2021).

"Design principles and detailed design issues" will be removed	"Design principles and detailed design issues" will be affected: Zebra cross	On-street parking	Off-street parking	Load and go (Drop points)	Traffic lights	Road signs	Roadsides (1, 2 or >3 lane)	Road separation	Roundabout/ intersection	Islands	Charging points	One way/ two ways	Restricted ways	Other
Zebra cross	6,3%	7,1%	0,0%	5,9%	0,0%	0,0%	9,1%	0,0%	5,9%	0,0%	0,0%	0,0%	6,7%	0,0%
On-street parking	37,5%	50,0%	37,5%	47,1%	35,7%	46,7%	54,5%	58,3%	52,9%	75,0%	46,7%	66,7%	53,3%	0,0%
Off-street parking	18,8%	14,3%	37,5%	29,4%	14,3%	26,7%	27,3%	33,3%	29,4%	25,0%	33,3%	25,0%	46,7%	0,0%
Load and go (Drop points)	18,8%	14,3%	0,0%	11,8%	0,0%	0,0%	9,1%	8,3%	23,5%	12,5%	6,7%	16,7%	13,3%	0,0%
Traffic lights	31,3%	42,9%	37,5%	58,8%	57,1%	53,3%	27,3%	50,0%	35,3%	37,5%	60,0%	41,7%	53,3%	0,0%
Road signs	56,3%	71,4%	87,5%	64,7%	71,4%	60,0%	72,7%	50,0%	64,7%	75,0%	60,0%	58,3%	60,0%	0,0%
Roadsides (1, 2 or >3 lane)	12,5%	0,0%	0,0%	5,9%	0,0%	6,7%	9,1%	8,3%	5,9%	12,5%	0,0%	0,0%	0,0%	0,0%
Road separation	18,8%	14,3%	37,5%	17,6%	14,3%	20,0%	27,3%	16,7%	11,8%	25,0%	13,3%	16,7%	13,3%	0,0%
Roundabout/intersection	25,0%	35,7%	25,0%	35,3%	21,4%	6,7%	18,2%	16,7%	29,4%	12,5%	26,7%	33,3%	26,7%	0,0%
Islands	25,0%	21,4%	12,5%	17,6%	14,3%	13,3%	18,2%	0,0%	17,6%	0,0%	20,0%	16,7%	20,0%	0,0%
Charging points	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
One way/ two ways	12,5%	7,1%	12,5%	5,9%	0,0%	6,7%	9,1%	0,0%	5,9%	12,5%	6,7%	8,3%	0,0%	0,0%
Restricted ways	43,8%	35,7%	37,5%	35,3%	28,6%	26,7%	27,3%	25,0%	41,2%	50,0%	26,7%	41,7%	33,3%	0,0%
Other	18,8%	14,3%	12,5%	23,5%	21,4%	20,0%	18,2%	16,7%	11,8%	25,0%	13,3%	25,0%	6,7%	100,0%

4.5.6 Hypothesis 6

This hypothesis examines the relationship between the affected MFS 1 design guidelines and the affected/removed design principles and design issues using a relative importance index. The structure of this hypothesis in shown in Table 4-28.

Table 4-28. Hypothesis 6 (Author, 2021)

Hypothesis 6	**Questions 11, 12 & 13**
To analyse the relationship between the affected and removed design principles and design issues and the Design guidance (MFS 1)	The impact of AVs on these design principles and design issues will have a significant impact on design guidance.

The relative importance index created to test this hypothesis is presented in Table 4-29. It reveals that parking received the most top rankings, being ranked first by a range of experts, including those who believe zebra crossings, on-street parking, off-street parking, traffic lights, road signs, and roundabouts/intersections will be affected or removed. However, experts who thought road size (1, 2 or 3+ lanes), road separation, one way / two way streets, and restricted ways would be affected or removed ranked layout and connectivity at the top. Meanwhile, traffic signs and markings and street users' needs were ranked top by those experts who thought zebra crossings, load and go (drop points), traffic lights, islands and restricted ways would be affected or removed. Based on analysis of the results in Table 4-29, the most affected MFS design guidelines are ranked as follow:

- Parking
- Traffic Signs and Marking
- Layout
- Quality of Place
- Street Users' Needs
- Street Geometry
- Street Furniture and Lighting

Table 4-29. Relative important index of the MFS Design Guidance in relation to the experts' views of the design principles and issues which will be affected or removed (Author, 2021).

		The affected and removed "Design principles and detailed design issues"												
		Zebra cross	**On-street parking**	**Off-street parking**	**Load and go (Drop points)**	**Traffic lights**	**Road signs**	**Roadsides (1, 2 or >3 lane)**	**Road separation**	**Roundabout/ intersection**	**Islands**	**One way/ two ways**	**Restricted ways**	**Other**
Affected MFS Design Guidelines	**Layout and connectivity**	0,80 (4)	0,86(2)	0,83 (2)	0,90 (3)	0,88(3)	0,84 (3)	1,00 (1)	0,95 (1)	0,83 (4)	0,91(2)	1,00 (1)	0,91 (1)	1,00 (1)
	Parking	1,00 (1)	0,89 (1)	0,94 (1)	0,95 (2)	0,89 (1)	0,91 (1)	0,60 (6)	0,85(2)	1,00 (1)	0,80 (3)	0,93 (2)	0,89 (3)	0,84(5)
	Quality of place	0,60(5)	0,71(7)	0,63(6)	0,85(5)	0,77(4)	0,76 (4)	0,80 (3)	0,80 (3)	0,85(3)	0,71(5)	0,73(5)	0,87 (4)	0,92 (2)
	Street furniture and lighting	0,2(6)	0,74 (5)	0,63(6)	0,60 (7)	0,71(7)	0,69(6)	0,80 (3)	0,60(7)	0,58 (7)	0,77 (4)	0,80 (4)	0,67(7)	0,84(5)
	Street geometry	0,60(5)	0,74 (5)	0,74 (4)	0,70 (6)	0,75(5)	0,71(5)	0,40(7)	0,75(6)	0,83 (4)	0,66	0,67(7)	0,69(6)	0,88 (4)
	Street user's needs	1,00 (1)	0,77 (4)	0,71(5)	0,90 (3)	0,72(6)	0,69(6)	0,80 (3)	0,80 (3)	0,73 (6)	0,71(5)	0,73(5)	0,73(5)	0,84(5)
	Traffic sign and markings	1,00 (1)	0,83 (3)	0,77 (3)	1,00 (1)	0,89 (1)	0,89 (2)	0,90 (2)	0,80 (3)	0,88 (2)	0,94(1)	0,93 (2)	0,91 (1)	0,92 (2)

The value in parentheses represents the rank of "Importance of the barrier "for the affected and removed design

4.5.7 Hypothesis 7

Hypothesis 7 (Table 4-30) looks at the relationship between the experts' forecasts about future AV ownership and their opinions about which domain (City planning, Regulation, or Vehicle Manufacturing) needs to be developed most urgently. In other words, it aims to discover whether the discipline identified is associated with increased or decreased AV ownership.

Table 4-30. Hypothesis 7 (Author, 2021)

Hypothesis 7	**Questions 1, 10 & 14**
*To examine the relationship between the experts' choice of domain to be developed first and their thoughts about future **AVs ownership**.*	**a.** Experts who selected "City Planning" as the first domain to develop expect **AV ownership** to increase. **b.** Experts who selected "Regulation" as the first domain to develop expect **AV ownership** to decrease. **c.** Experts who selected "Vehicle manufacturing" as the first domain to develop expect **AV ownership** to increase.

A comparison of the experts' responses regarding the domain which should be prioritised for development and the forecast of future car/AV ownership is presented in Table 4-31. As can be seen, 53.2% of the experts who think regulation should be prioritised foresee a decrease in future AV ownership, as do 53.8% of those who would prioritise vehicle manufacturing. Those who would prioritise City planning are split, with 35.3% forecasting a decrease and 41.2% an increase in future ownership. However, analysis of the association between domain and future ownership shows the absence of a statistical association ($P > 0.05$).

Future AVs ownership	Domain needed to be developed				Active Margin
	City Planning	Regulations	Vehicle Manufacturing	Other	
Decrease	35.3%	53,8%	53.8%	100,0%	15
Increase	41.2%	15,4%	15.4%	0,0%	10
Neither	11.8%	15,4%	15.4%	0,0%	7
Other	11.8%	15,4%	15.4%	0,0%	4
Active Margin	17	13	5	1	36
P-value (independence test)	**0.397^{NS}**				

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the colon variable and the row variable at P≤ 0.05.

Table 4-31. Relationship between the domain to prioritise for development and future AV ownership (Author, 2021).

The analysis of the multiple correspondences is presented in Table 4-32 and Figure 4-21. This reveals a certain resemblance between the choice of regulation as the domain for development and a forecast decrease in future AV ownership and the choice of city planning and an increase in future AVs ownership. However, the development of vehicle manufacturing seems to have no influence on the future of AV ownership.

Table 4-32. Correspondence scores of domain needing to be developed and future AV ownership (Author, 2021)

Correspondence points	Score in Dimension	
	1	**2**
Domain needing to be developed		
City Planning	0.219	-0.529
Regulations	0.259	0.512
Vehicle Manufacturing	-1.598	0.148
Other	0.900	1.593
Future AV ownership		
Decrease	0.382	0.478
Increase	0.107	-0.843
Neither	-1.293	0.196
Other	0.564	-0.028

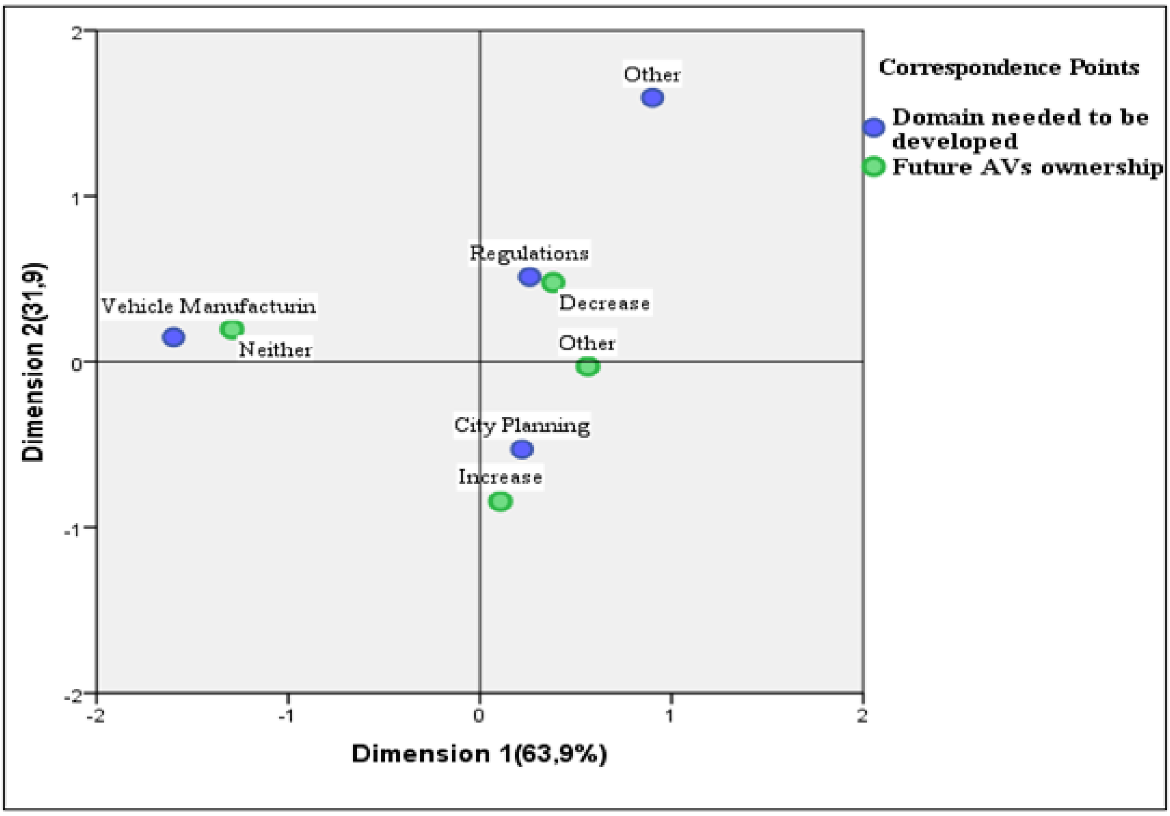


Figure 4-21. Correspondence analysis plot of domains needing to be developed and future AV ownership (Author, 2021).

4.5.8 Hypothesis 8

Hypothesis 8 considers whether the location and type of AV parking will affect future ownership. The hypothesis assumes that AV ownership will increase if specific hubs are created for full AVs. Also, an increase in ownership is expected if these hubs are built in each neighbourhood. This hypothesis is divided into two elements, as shown in *Table 4-33*.

Table 4-33. Hypotheis 8 (Author, 2021)

Hypothesis 8	**Type of Parking (Question 14 & 15)**
To study the relationship between parking types and locations and their effect on future AVs ownership	**a.** AV ownership will increase if underground/overground hub parking, particularly for AVs, is created. **b.** AV ownership will decrease if underground/overground hub parking, particularly for AVs, is created. **Location of Parking (Question 14 & 16)** **a.** AV ownership will increase if parking areas are located in each neighbourhood.

b. AV ownership will decrease if parking areas are in the city centres or on the outskirts."

4.5.8.1 Hypothesis 8.1 (Ownership *vs* Type of parking)

The first element explores the relationship between the experts' predictions about future AV ownership and their choice of the most appropriate types of parking (storage) for AVs. The results are shown in Table 4-34.

Table 4-34. Cross-tabulation between future AV ownership and type of parking (Author, 2021).

Type of Parking	**Future AVs ownership**				
	Decrease	**Increase**	**Neither**	**Other**	Active Margin
Underground or overground parking hubs created for AVs	33.3% (5)	20.0% (2)	57.1% (4)	25.0% (1)	12
Existing parking in the city	33.3% (5)	50.0% (5)	28.6% (2)	50.0% (2)	14
Existing parking at large supermarkets such as Asda, Tesco, etc.	33.3% (5)	20.0% (2)	0.0% (0)	0.0% (0)	7
Other	0.0% (0)	10.0% (1)	14.3% (1)	25.0% (1)	3
Active Margin	15	10	7	4	36
P-value (independence test)		**0.397^{NS}**			

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the colon variable and the row variable at P≤ 0.05. The chi-square test was adjusted by Fisher's Exact test.

The statistical model is not significant (P-value of association test> 0.05), which means that there is no significant statistical relationship between future AV ownership and the development of different types of parking. However, analysis of the correspondence between the experts' forecasts about future AV ownership and their opinions about the most appropriate parking types (See Figure 4-22 and Table 4-35) shows a connection between the use of existing parking in the city and an increase in future AV ownership. By contrast, the use of existing parking at supermarkets such as Asda and Tesco is linked to a decrease in

AV ownership. Meanwhile, the creation of underground or overground parking hubs especially for AVs does not seem to influence future AV ownership in any way.

Table 4-35. Correspondence scores of future AV ownership and parking types (Author, 2021).

Correspondence points score in AFC dimension		
Correspondence points	**Score in Dimension**	
	1	**2**
Future AV ownership		
Decrease	-0.654	0.178
Increase	0.002	-0.571
Neither	0.795	0.787
Other	1.055	-0.620
Parking types		
Create underground/overground parking hubs particularly for AVs (CUOPH)	0.190	0.712
Existing parking in the city (EPC)	0.074	-0.435
Use parking at large supermarkets such as Asda, Tesco, etc. (UPLS)	-1.098	-0.133
Other	1.454	-0.504

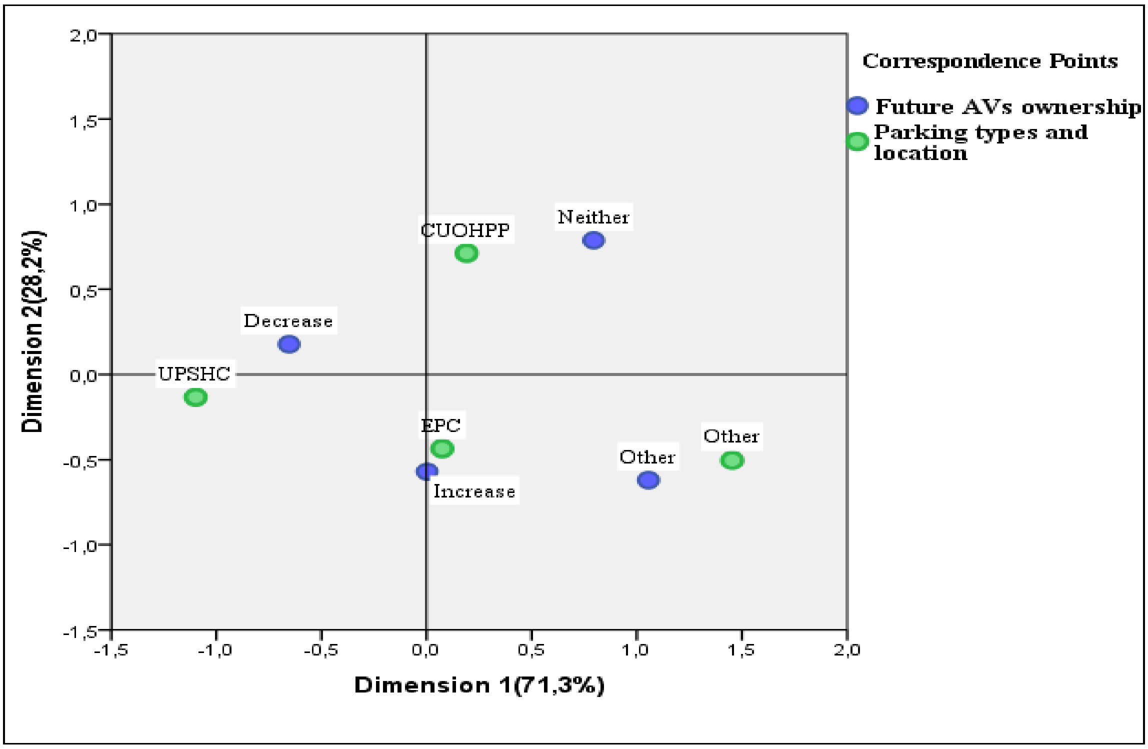


Figure 4-22. Correspondence analysis plot of future AV ownership and parking types (Author, 2021).

4.5.8.2 Hypothesis 8.2 (Ownership Vs location of parking)

The second element explores the relationship between the experts' predictions about future AV ownership and their choice of the most appropriate locations for parking hubs for AVs. The results are shown in Table 4-36.

Table 4-36. Cross-tabulation between future AV ownership and parking location (Author, 2021).

Creating specific parking (Hubs) location	**Future AVs ownership**				Active Margin
	Decrease	**Increase**	**Neither**	**Other**	
In each neighbourhood	73.3% (11)	80.0% (8)	14.3% (1)	50.0% (2)	12
In city centres	13.3% (2)	0.0% (0)	71.4% (5)	0.0% (0)	14
On the outskirts	0.0% (0)	20.0% (2)	0.0% (0)	0.0% (0)	7
Other	13.3% (2)	0.0% (0)	14.3% (1)	50.0%(2)	3
Active Margin	15	10	7	4	36
P-value (independence test)	**≤0.001*** **				

The value in parentheses represents the absolute frequency of the category. ***: The dependence is statistically significant between the colon variable and the row variable at P≤0.001. The chi-square test was adjusted by Fisher's Exact test.

As Table 4-36 illustrates, the statistical model is significant and demonstrated a highly effective association ($P \leq 0.001$). Therefore, the independent variable predicts the dependent variable significantly, and we can explain a positive relationship between the two variables. This means that the location of hubs will impact future car ownership. In addition, the results of the correspondence analysis (See Table 4-37 and Figure 4-23) illustrate that creating specific parking hubs in each neighbourhood and on the outskirts of cities seems to exert an influence on the forecast increase in future AV ownership. By contrast, locating hubs in city centres did not appear to affect forecast changes in car ownership.

Table 4-37. Correspondence score of future AV ownership and location of dedicated AV parking hubs (Author, 2021).

Correspondence points score in AFC dimension		
	Score in Dimension	
Correspondence points	**1**	**2**
Future AVs ownership		
Decrease	-0.117	0.241
Increase	-0.883	-0.664
Neither	1.563	-0.447
Other	-0.089	1.540
Location of dedicated AV parking hubs		
In each neighbourhood	-0.454	-0.003
In the city centres	1.552	-0.558
In the outskirts	-1.265	-1,479
Other	0.330	1.387

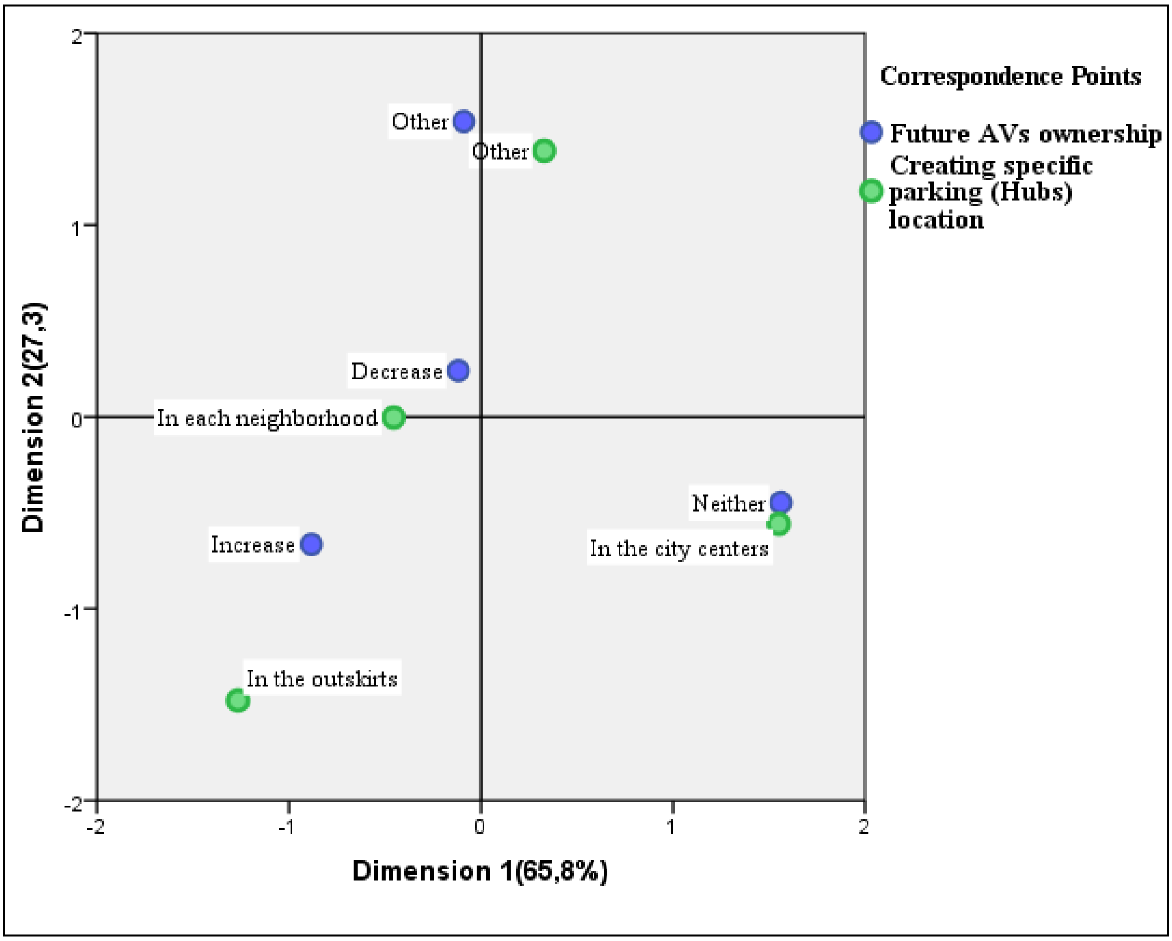


Figure 4-23. Correspondence analysis plot of future AV ownership and locations of dedicated AV parking hubs (Author, 2019).

4.5.9 Hypothesis 9

This hypothesis looks at whether there is a relationship between driving mode when adopting AVs fully and the anticipated changes in car ownership. It assumes that experts who are in favour of banning manual driving expect AV ownership to decrease and those who believe that manual driving should not be prohibited expect increased car ownership. The structure of this hypothesis is shown in Table 4-38

Table 4-38. Hypothesis 9 (Author, 2021)

Hypothesis 9	**Questions 14 & 18**
To analyse the relationship between manual driving and AV ownership	**a.** Experts who said "Yes" manual driving should be banned are expecting AV ownership to decrease.

b. Experts who said "No" manual driving should not be banned are expecting AV ownership to increase.

The results of the analysis are provided in Table 4-39. As the table demonstrates, the association between future AV ownership and manual driving is not statistically significant (P-value of your association> 0.05). A large part of experts predicts that manual driving is independent of future AV ownership. Nevertheless, in the multiple correspondence analysis (See Table 4-40 and Figure 4-24), there is a link between predictions of a decrease in future AV ownership and banning manual driving and an increase in future AV ownership and allowing manual driving to continue.

Table 4-39. Cross-tabulation between banning manual driving and future car ownership (Author, 2021).

Should manual driving be banned?	**Future AVs ownership**				Active Margin
	Decrease	**Increase**	**Neither**	**Other**	
Yes	26,7% (4)	20,0% (2)	14,3% (1)	0,0% (0)	7
No	66,7% (10)	70,0% (7)	85,7% (6)	25,0% (1)	24
Other	6,7% (1)	10,0% (1)	0,0% (0)	75,0% (3)	5
Active Margin	15	10	7	4	36
P-value (independence test)	**≤0,100NS**				

The value in parentheses represents the absolute frequency of the category. NB: The dependence is statistically insignificant between the colon variable and the row variable at P≤ 0.05. The chi-square test was adjusted by Fisher's Exact test.

Table 4-40. Correspondence score of banning manual driving and future car ownership (Author, 2021).

Correspondence points	**Score in Dimension**	
	1	**2**
Future AVs ownership		
Decrease	-0,273	-0,355
Increase	-0,140	0,042
Neither	-0,487	0,648
Other	2,227	0,091
Manual driving		
Yes	-0,290	0,223

No	1,978	-0,058
Other	-0,419	-0,724

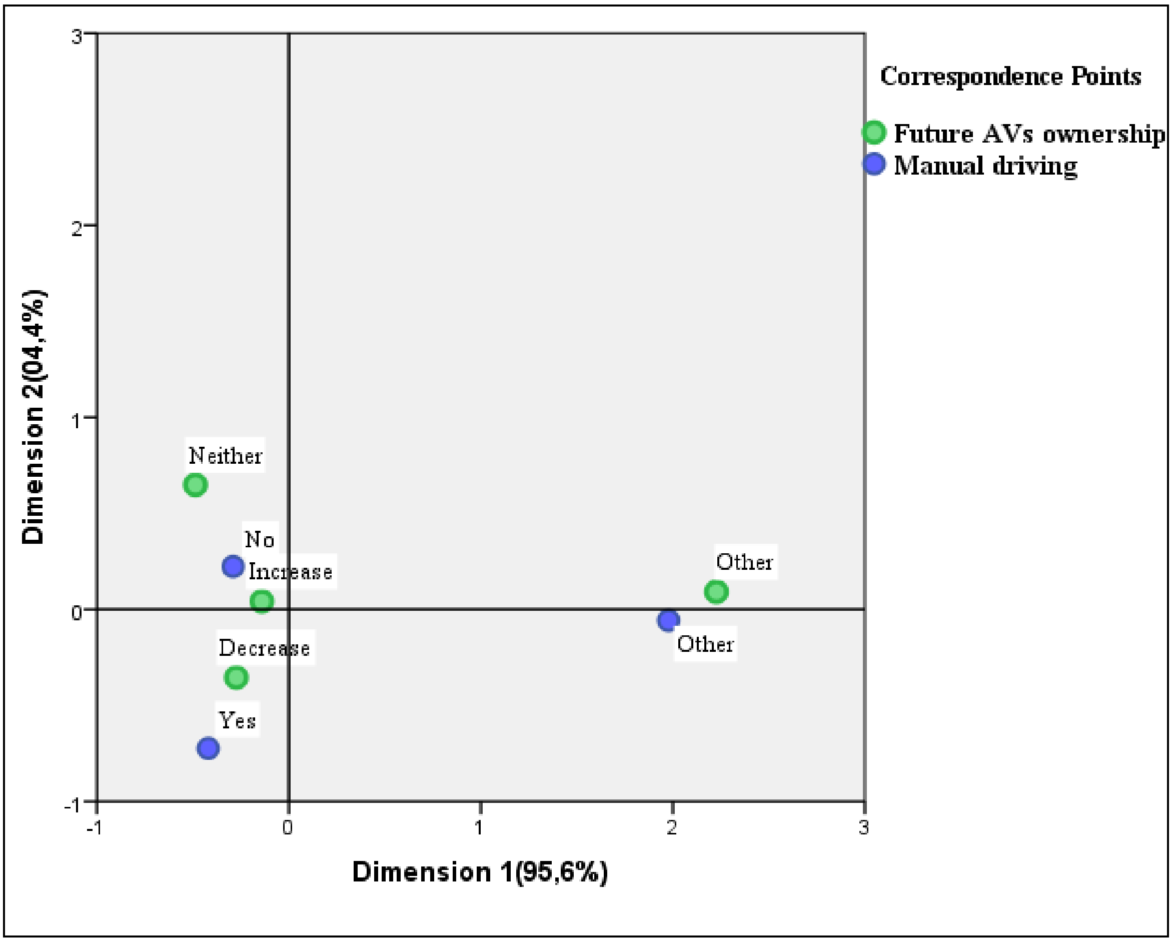


Figure 4-24. Correspondence analysis plot of future AV ownership and banning manual driving (Author, 2021)

4.6 Conclusion

This chapter aimed to address Objectives 1 and 3 and answer the following research questions: 'By which methods and strategies can autonomous cars be integrated into the city transportation infrastructure?' and 'Will AVs change the city's urban structure?' Quantitative and qualitative methods were used to collect data and a survey questionnaire was utilised. NVivo 12 Pro was used to analyse the open-ended questions and SPSS to analyse the closed-ended questions. This phase of the study examined the conceptual framework developed in Chapter 2 by analysing the opinions of the expert respondents in respect of its contents, in particular: (i) to what extent did they agree/disagree with the framework contents, (ii) does it include the right elements, (iii) does it include all the barriers and vehicle specifications, and, (iv) are there further barriers to be investigated? The experts also analysed, rated and ranked the barriers in order of importance. Issues such as time expectations for AV adoption and the domains that need to be developed first (City planning, Regulations or Vehicle Manufacturing) were also investigated and the mostly commonly selected responses identified.

The experts were also asked to analyse a proposed journey through the centre of Nottingham (moving from point A to point B) to consider how street design elements would be affected if the vehicle making the journey was a full AV (Level 4). More precisely, this analysis investigated the expected impacts of AVs on urban planning, particularly design principles and detailed design issues, and design guidelines, based on the MFS, and considered which were likely to be *affected* by AV adoption and which were likely to be *removed* completely. As a result, the top seven elements which were most likely to be affected or removed were identified. Further analysis also identifed and ranked the MFS design guidelines which were most likely to be affected, and the experts' views of the most appropriate types and locations of AV parking facilities were also identified. The questions of whether manual driving should be banned once AVs are fully implemented and whether they are likely to increase or decrease car ownership were also addressed. Nine hypotheses were then formulated and tested to validate the framework and examine the experts' opinions in more detail.

Chapter 5: Autonomous Vehicles and User Acceptance Behaviour

Chapter 5: : Autonomous Vehicles and User Acceptance Behaviour

5.1. Introduction

Public opinion is crucial to determining whether the potential benefits of adopting AVs will be achieved (Liljamo et al., 2018). As a result, Phase III of the practical implementation explored users' acceptance behaviour regarding AVs in order to address Objective 4 of this study. This involved the creation and distribution of an online survey targeting members of the public in Nottingham, the case study city. The survey was designed to establish the respondents' views relating to the critical themes in relation to user acceptance and behaviour identified in the literature review in Chapter 2 (See Figure 2-10). Systematic sampling was used, and a sample size of 138 respondents was identified (See Chapter 3). The survey was conducted using the specialist academic survey platform *onlinesurvey.ac.uk*. A copy of the survey is provided in Appendix 2.

Both quantitative and qualitative methods were used to analyse the data collected in this survey. Most of the questions included an "Other" option, to enable respondents to make comments and provide further behavioural data for analysis, so SPSS was utilised to explore the responses to the closed questions, and NVivo Pro 12 to analyse the open-ended questions and the "Other" responses. As with the experts' survey, a series of hypotheses were formulated and tested using different statistical analyses (using SPSS) to validate the survey findings and explore the results in more detail. The main themes and hypotheses examined in the survey, the measures taken to check reliability, the results, and the outcomes of the hypothesis testing are described below.

5.2. Survey Themes and Research Hypotheses

5.2.1. Survey Themes

The themes explored in the survey were those identified in the literature review in Chapter 2, with two notable exceptions. Although cost was identified as a key factor influencing people's willingness to adopt AVs, it was not considered in this study for two reasons. Firstly, accurate costs for AVs are still unclear. Secondly, even where estimated costs are available, these are likely to decrease significantly before AVs are widely adopted (Babbar & Lyons, 2017). Thus, it was not considered appropriate to include cost over concerns it would bias the behaviour study. Meanwhile, an additional factor was identified for investigation in this survey: the potential disappearance of sports vehicles and driving enjoyment after full AVs adoption. As a result, the survey themes were structured as follows:

- Modes of moving and travelling either in the city or long distances
- Types of vehicles participants own or use
- Awareness of AVs and general thoughts about them
- Overall considerations of and desire to own or share AVs
- Expectations of the benefits of AVs and the experience of travelling inside one
- Big data and their willingness to share their data
- Allocation of responsibility in case of an accident
- Feelings about the disappearance of sports vehicles after full adoption of AVs
- General opinions about the current obstacles and barriers to AV adoption

The first part of the survey 'Conventional cars vs AVs' explored these themes in detail; the second part 'Participants' information' collected respondents' demographic data.

5.2.2. Research Hypotheses

As mentioned above, SPSS and NVivo Pro 12 were used to analyse the responses and then test a number of hypotheses; these are presented in Table 5-1 and Table 5-2.

Table 5-1. Summary of the hypotheses, Survey 2 (Part 1) (Author, 2021)

Hypotheses (Alternative)	**Sub-Hypotheses**
Hypothesis 1 *Participants mode of transport (either in or between cities) and the expected behaviour*	**In the city (Questions 1 & 6)** **a**. Participants who use Public transport (e.g. Taxi, Bus, Tram, Train, Carpooling) are more likely to want to share an AV. **b**. Participants who use private cars are expected to want to own an AV. **Between cities (Questions 2 & 6)**

when using AVs (share/own)	**c**. Participants who use Public transport (e.g. Taxi, Coach, Train, Carpooling) are likely to want to share an AV. **d**. Participants who use private cars are expected to own an AV.
Hypothesis 2 *Type of car(s) owned has a significant impact on level of concern about the disappearance of sports cars*	**Questions 3 & 11** **a**. Participants who own or use these type of cars (hatchback, saloon, MPV) will not be concerned about the disappearance of sports vehicles. **b**. Participants who own or use SUVs, crossovers, coupes or convertibles will be very concerned about the demise of sports vehicles.
Hypothesis 3 *Familiarity with AVs and opinion about them*	**Questions 4 & 5** **a**. Participants who have heard of AVs are more likely to be positive about them. **b**. Participants who have not heard or not sure of AVs are more likely to feel negative about them.

Table 5-2. Summary of the hypotheses (Part 2) (Author, 2021).

Hypothesis 4 *Familiarity with AVs, attitude towards them, and desire to own/share one affects willingness to share data*	**Questions 5, 6 & 8** **a**. Participants who have heard of AVs, feel positive about them, and want to own an AV are likely to want to share their data. **b**. Participants who have not heard of AVs, feel more negative, and neither want to own nor share one (neither) are unlikely to want to share their data.
Hypothesis 5 *AV type of ownership and type of transportation mode affect the view of the party held liable in case of an accident*	**Questions 1 & 2 and Questions 6 & 10** **a**. Participants who want to own AVs and currently use private cars blame manufacturers. **b**. Participants who want to own AVs and currently use private cars blame insurance companies. **c**. Participants who want to own AVs and currently use private cars blame all the above. **d**. Participants who currently use public transport (e.g. Taxi, Bus, Tram, Train, Carpooling) and want to share AVs blame city planners and AV owners.
Hypothesis 6 *Type of vehicle owned/used currently predict the future use of AVs (Own/share)*	**Questions 4 & 5** **a.** Participants who own hatchbacks, saloons, and/or MPVs would desire to own AVs in the future

5.11 Section (5.11) explores these hypotheses in detail and explains how they were tested.

5.3. Reliability Check (Cronbach's Alpha)

Assessing the consistency of internal data involves measurement of reliability and the degree to which the methods adopted have produced consistent results. There is a debate about whether Cronbach's alpha test is a suitable report to measure the internal consistency of data. (McNeish, 2018) argues that various alternative measures can provide justifiable reliability levels compared to Cronbach's alpha. However, (Tavakol & Dennick, 2011) stress that Cronbach's alpha is a critical element in evaluating data gathered via a questionnaire. As a result, Cronbach's alpha was chosen to measure the reliability of the survey data.

Cronbach's alpha is a computational test that correlates the score for each scale variable or item concerning the total score for each observation. Then it compares that to the variance for all individual variable scores. The resulting alpha ranges from 0 to 1. The recommended standards that dictate an "acceptable" alpha coefficient depend on the theoretical knowledge applied and the subject studied. However, many researchers recommend a minimum alpha coefficient between 0.65 and 0.8. According to (Mohamad et al., 2015) the value of alpha can be interpreted as follow (α <.67 is poor; α= 67-.80 is Fair; α= 81-.90 is Good; α= 91-.94 is Very Good; and α >.94 is Excellent). Table 5-3 illustrates the Cronbach's alpha test results for this survey.

Table 5-3. Cronbach's alpha test results (Author, 2021)

Reliability Statistics		
Survey Section	**Cronbach's Alpha**	**No. of Items**
Conventional cars vs AVs	0,668	49
Participants' information	0.712	6
Total	0.695	55

As the table shows, the overall alpha value for this study is 0.695, which falls into the Fair category. This means the results are reliable and valid. The result for Section 1 (Conventional cars *vs* AVs) is 0.668, which indicates an acceptable level (Fair) of internal consistency. The alpha for section 2 (Participants' information) is 0.712, which also indicates a fair level of internal consistency for this section.

5.4. Participants' Demographic Details

Table 5-4 depicts the overall demographic data of the respondents. The majority of respondents were male (54%), and respondents aged 25-34 or 35-44 comprised more than 55% of the total sample across both genders. However, in the 55-64 age group, there were significantly more male participants (7.14%) than females (2.14%). Most respondents were employed (65.71%), with 29.29% for females and 35.71% males. In terms of education, the largest categories are Bachelor and Master/PhD, with 12.14%, 12.14 and 12.86, 23.75% for females and males respectively. These categories are discussed in more detail below.

Table 5-4. Summary of the demographic details of the sample studied (Author, 2021).

Demographic information		**Total (%)**	
		Female (46%)	Male (54%)
Age group (%)	Under 21	6.43	1.43
	21-24	11.43	2.86
	25-34	11.43	16.43
	35-44	10.00	20.00
	45-54	4.29	5.00
	55-64	2.14	7.14
	65- or older	0.00	0.71
Occupation (%)	Student	12.14	10.71
	Employee	29.29	35.71
	Self-employed	2.86	3.57
	Retired	0.00	1.43
	Unable to work	0.71	1.43
	Other	0.71	0.71
Education	High school	7.86	7.14
	College	12.86	9.29
	Bachelor	12.14	12.86
	Master/PhD	12.14	23.57
	Other	0.71	0.71
Type of Car	Hatchback	20.71	17.86
	Saloon	8.57	12.14
	MPV	4.29	4.29
	Sports utility vehicle (SUV)	4.29	6.43
	Crossover	1.43	5.00
	Coupe	1.43	3.57
	Convertible	0.71	2.14

	Other	4.29	1.43
Mode of travel in the city	Private car	6.67	12.22
	Taxi	2.96	5.19
	Bus	8.89	14.07
	Bicycle	2.22	4.07
	Tram	7.04	4.07
	Train	0.37	2.59
	Walking	14.81	12.59
	Carpooling	0.00	0.74
	Other	0.00	0.74
Mode of travel between cities (Long distances)	Private car	16.89	18.26
	Taxi	2.28	0.91
	Coach	8.22	12.79
	Train	16.89	17.35
	Carpooling	2.74	0.91
	Other	0.91	0.91

The following sections explore the participants' information in more details and describe the studied sample in-depth:

5.4.1. Participants' age description

The first question in this section asked participants to indicate which age category they occupied. The whole sample was taken into consideration for the analysis of this question. The results are shown *in* Table 5-5.

Table 5-5. Which of the following categories best describes your age? (Author, 2021).

	Frequencies	Percentages
Under 21 years	11	7.9
21-24	20	14.3
25-34	39	27.9
35-44	42	30
45-54	13	9.3
55-64	14	10
65 or older	1	0.7
Total	140	100
Missing	0	0

As Table 5-5 shows, the proportion of participants in each age category was as follows:

- 42 (30%) participants were aged from 35 to 44 years old;
- 20 (27.9%) participants were aged from 25 to 34 years old;

- 20 (14.3%) participants were aged from 21 to 24 years old ;
- 14 (10%) participants were aged from 55 to 64 years old;
- 13 (9.3%) participants were aged from 45 to 54 years old;
- 11 (7.9%) participants were aged under 21 years old;
- 1(0.7%) individual was aged 65 years or older;

This information can be represented graphically, as shown in Figure 5-1:

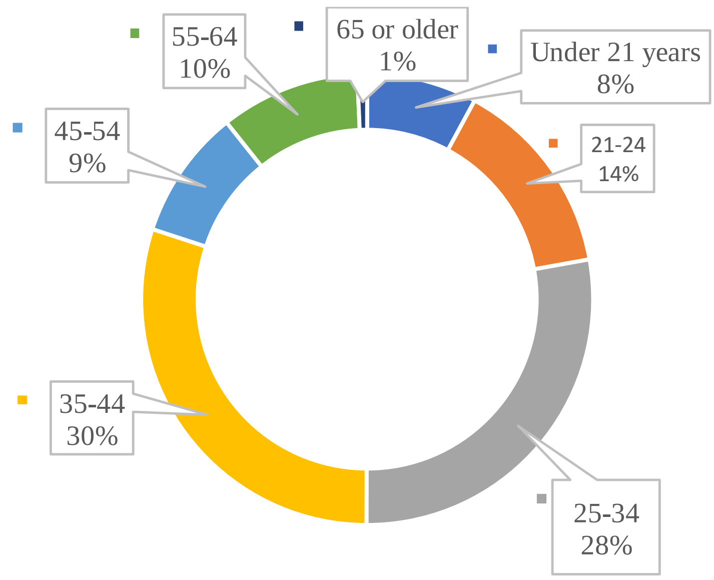


Figure 5-1. Q14: Which of the following categories best describes your age? (Author, 2021).

5.4.2. Participants' gender

140 participants took part in the survey from both genders, and the whole sample was taken into consideration for the analysis. As shown in Table 5-6, 76 (54.3%) Males and 64 (45.7%) Females participated and there was no significant difference between gender categories (8.6% difference). An option to state another gender was included, but the results were 0%.

Table 5-6. Participants' gender (Author, 2021).

	Frequencies	Percentages
Female	64	45.7
Male	76	54.3
Others	0	0
Total	140	100

Missing	0	0

5.4.3. Participants' occupation

Participants were the asked to identify the most suitable employment category from a list five suggested categories (student, employee, self-employed, retired and unable to work). An "Other" option was also included. The whole sample was taken into consideration for the analysis of this question. The results are shown in Table 5-7. Based on the highest percentages, the most popular occupation categories were:

- Employees - 93 (66.4%);
- Students - 31 (22.1%);
- Self-employed - 9 (6.4%);
- Retired - 2 (1.4%);
- Other – 2 (1.4%)

Of the respondents who selected "Other", one indicated that they were seeking a job and the other was working part-time and studying.

Table 5-7. Participants' occupation distribution (Author, 2021).

	Frequencies	**Percentages**
Student	31	22.1
Employee	93	66.4
Self-employed	9	6.4
Retired	2	1.4
Unable to work	3	2.1
Other	2	1.4
Total	140	100
Missing	0	0

5.4.4. Distance participants travel between home and work or study

It was important to establish how far participants usually travel from their home to their place of work or study in order to understand how this related to the mode of transport used and to consider how the adoption of AVs might impact this. 144 responses were received, so the whole sample was taken into consideration for the analysis of this question.

The results are shown in Table 5-8. As the results show, the highest category was 1 to 3 miles (ca. 5 km) with 39 (27.9%) of participants living within this range. The next most popular category was 3 to 5 miles (ca. 8 km) with a 1.5% difference between the first category. 21 (15%) participants lived within 5 to 10 miles (ca. 16 km) and 20 (14.3%) within 10 to 25 miles (ca. 40 km). The categories that represent the shortest journeys (0 to 1-mile [1.61 km]) and the longest (over 50 miles [ca. 80 km]) had the lowest percentages at 18 (12.9%) and 5 (3.6%), respectively.

Table 5-8. Distance from participants' homes to their places of work or study (Author, 2021).

	Frequencies	Percentages
0-1 miles	18	12.9
1-3 miles	39	27.9
3-5 miles	37	26.4
5-10 miles	21	15
10-25 miles	20	14.3
Over 50 miles	5	3.6
Total	140	100
Missing	0	0

5.4.5. Participants' marital status

Participants were then asked to indicate their marital status from a choice of four options (Single, Married, Divorced, and Other). The distribution of the participants' marital status is shown in Figure 5-2.

	Frequencies	Percentages
Single	62	44.3
Married	63	45
Divorced	10	7.1
Other	5	3.6
Total	140	100
Missing	0	0

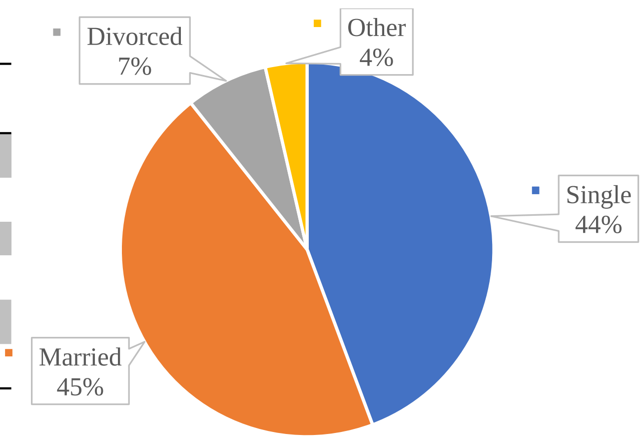


Figure 5-2. Distribution of the participants' marital status (frequencies and percentages) (Author, 2021).

As Figure 5-2 illustrates, the "single" and "married" groups make up most of the study sample, with 63 (45%) 62 (44.3%) respectively. 10 (7.2%) of the participants are divorced while 5 (3.6%) represent the "Other" group.

5.4.6. Participants' level of education

Participants were also asked about their level of education in order to analyse and understand how different levels of education affect users' behaviour in adopting AV technology. Four choices were suggested (High school, College, Bachelor, and Master/PhD) and an "Other" option was provided. Table 5-9 illustrates the results obtained from the whole sample.

Table 5-9. Participants' level of the education distribution (Author, 2021).

	Frequencies	**Percentages**
High school	23	16.4
College	31	22.1
Bachelor	34	24.3
Master/PhD	49	35
Other	3	2.1
Total	140	100
Missing	0	0

As the table demonstrates, the highest percentage of respondents had a Masters or PhD qualification (35%); this is most likely due to the fact that participants were recruited via university links and academic platforms. The next highest were bachelors' degree-level followed by college level, with 24.3% and 22.1%, respectively. Participants with high school diplomas constituted 16.4% of the total respondents. 3 participants (2.1 %) selected "Other", and said they had none of the listed qualifications. One provided "ASSOC CLPD" as an alternative qualification.

5.5. Participants' Views about AVs vs Conventional Vehicles

Respondents were also asked a series of questions to explore their attitudes and behaviours in respect of the themes identified in relation to user acceptance and behaviour identified in the literature review in Chapter 2 and set out in 5.2.1 above. The first of these questions asked respondents about their preferred modes of transport over both short and long distances.

5.5.1. Participants' preferred modes of transport (over short and long distances)

In order to assess travel preferences over short and long distances, the participants were asked about their transport preferences within the city of Nottingham and when travelling between cities.

5.5.1.1. Travelling within the city (short distances)

Respondents were asked how they usually moved around in the city and asked to select an option from a list of eight modes of transport (Private car, Taxi, Bus, Bicycle, Tram, Train, Walking, Carpooling) and an "Other" option. The results are shown in Figure 5-3. As the figure demonstrates, the three main modes were walking (28%), bus (23%) and private car (19%). Together, these modes received more than two-thirds of the total responses.

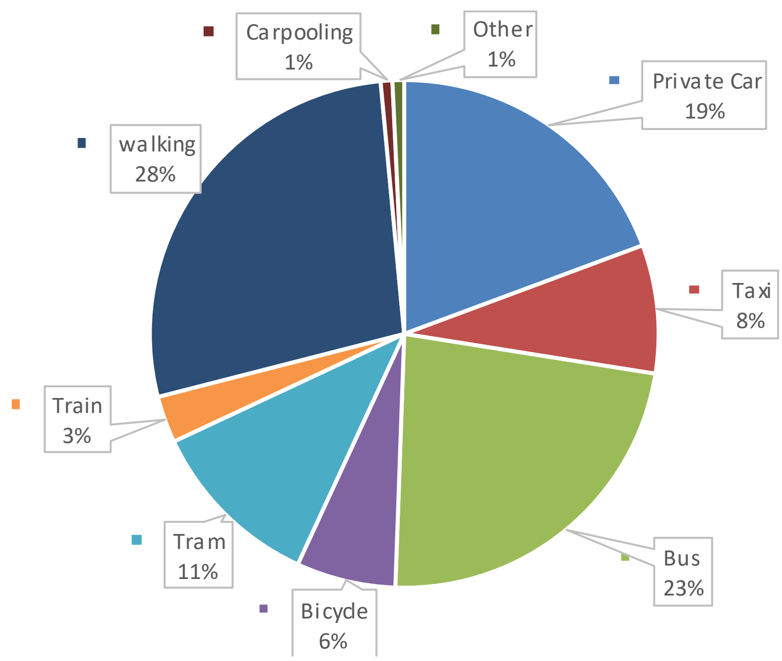


Figure 5-3. Distribution of respondents' preferred modes of transport in the city (Author, 2021)

Nottingham has a tram line which runs right through the city centre, and, according to (Robinson, 2019), recent upgrades to the tram network have *"put a third of people living in*

Greater Nottingham within 800m of a tram stop". However, the tram appears to be one of the lesser used modes for travel within the city at 11%. This suggests that further planning actions could be taken focusing on public transport and walking to reduce private car use.

5.5.1.2. Travelling between cities (long distances)

The respondents were then asked a similar question about the usual way they travel between cities or over long distances and six options were provided (Private car, Taxi, Coach, Train, Carpooling, and Other). As Figure 5-4 illustrates, private cars were the most widely used mode of transport (36%), followed by trains (34%) and coaches (21%). According to (Cavoski, 2019), based on passenger kms, the private car is still the most common means of transport, and this aligns with the results obtained from this survey.

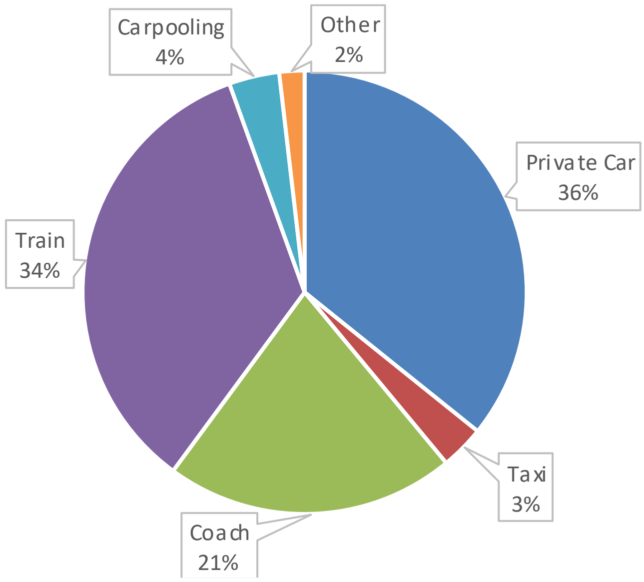


Figure 5-4. Distribution of respondents' preferred modes of transport between cities (or over long distances) (Author, 2021)

These statistics relate to the question of penetration rates and provide data for analysis about where to start implementing AVs. For instance, would it be more effective if AVs were implemented first on roads which link cities, such as motorways?

5.5.2. Type of vehicles participants own or use

The next question asked participants to select the type of car they currently use from a list of options: Hatchback, Saloon, Multi-purpose vehicles (MPV), Sports utility vehicle (SUV), Crossover, Coupe, Convertible, or Other). Illustrations of each where type were provided for ease of identification. The results are presented in Figure 5-5.

As can be seen, hatchback and saloon type cars were most widely used or owned by respondents, with 39% of respondents selecting hatchbacks and 21% selecting saloon types. The proportions selecting MPVs, or SUVs were similar at 11% and 9%, respectively

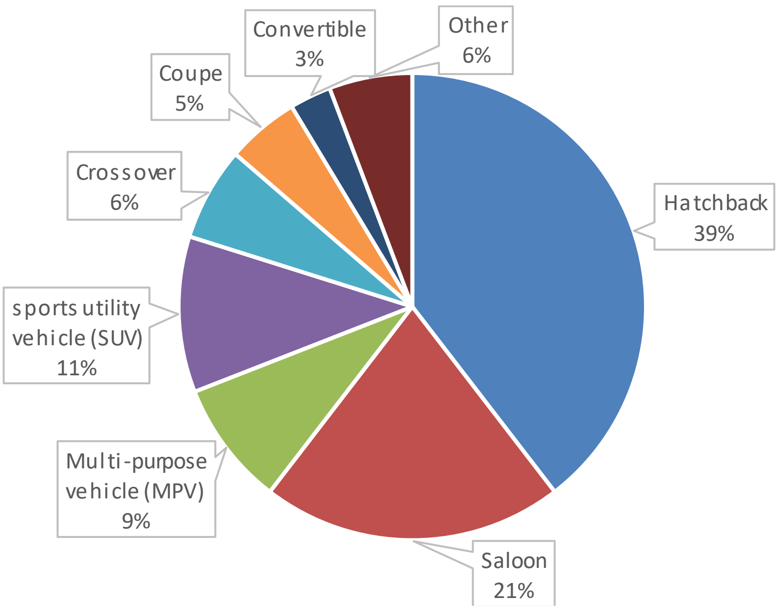
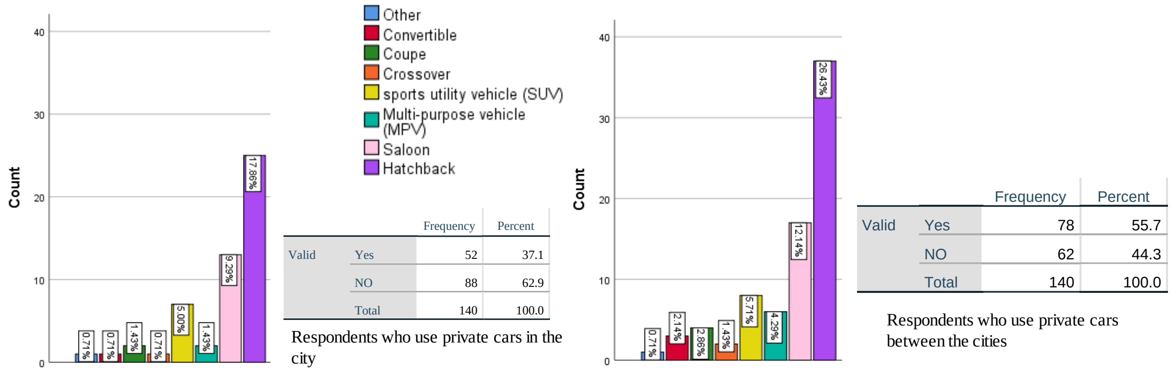


Figure 5-5. Distribution of the types of car respondents own or use at the moment (Author, 2021).

According to recent UK vehicle licensing statistics, *"The Ford Fiesta was the most current new car registration in 2018, with 95,000 registered for the first time. This was followed by the Volkswagen Golf with 66,000 and Vauxhall Corsa with 52,000"* (Parry, 2019). These are all hatchback type vehicles. The results of this study indicate that the hatchback is the most widely used type in Nottingham and therefore aligns with these statistics.

Cross-tabulation analysis was then conducted to examine the relationship between respondents who indicated that they used a private car in the city and between cities and the type of vehicle they own or use. The results are shown in Figure 5-6.



		Frequency	Percent
Valid	Yes	52	37.1
	NO	88	62.9
	Total	140	100.0

Respondents who use private cars in the city

		Frequency	Percent
Valid	Yes	78	55.7
	NO	62	44.3
	Total	140	100.0

Respondents who use private cars between the cities

Figure 5-6. Cross-tabulation analysis of respondents' use of a private car in the city and between cities and the type of vehicle they own (Author, 2021).

As the data in Figure 5-6 illustrates, 37.1% of respondents use a private car in the city whereas 55.7% use one between cities (long distances). It is evident that the hatchback type of car is the most widely used, both in the city and between the cities, with saloon types a distant second. The usage of other vehicles types are similar; however, there is a slight change in the use of MPVs in the city and between cities, at 1.43% and 4.29%, respectively. This raises the question: *What type of car should an AV be?*

5.5.3. Participants' awareness and perceptions of AVs

The next set of questions asked respondents about their levels of awareness of AVs, their overall perceptions of them, and whether they would like to own an AV in future.

5.5.3.1. Familiarity with AVs

The first question asked respondents if they had ever heard of AVs, driverless cars, or automated cars before taking part in this survey. As Figure 5-7 demonstrates, the vast majority of respondents (79%) had heard of driverless cars (AVs) and were familiar with the technology. 11% said "No" and 10% said "Not sure". Even though a definition of AVs was included in the survey to ensure the reliability and generality of the question, it is clear that a considerable percentage of respondents (21%) were not familiar with the technology.

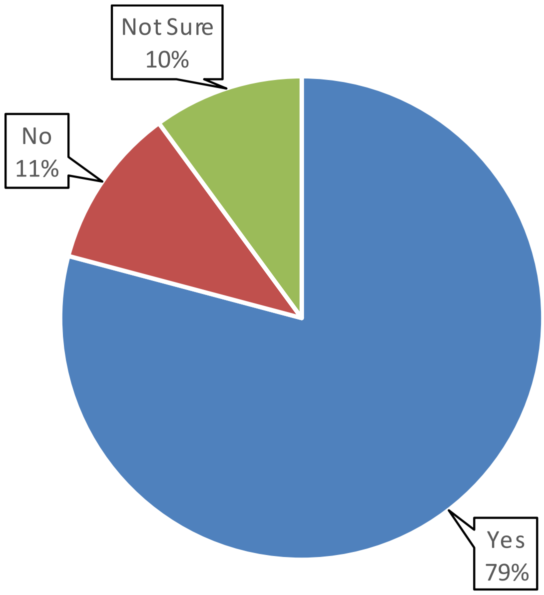


Figure 5-7. Participants' responses to Q4: Have you ever heard of autonomous, driverless or automated cars before taking part in this survey? (Author, 2021)

Cross-tabulation analysis was then conducted to examine the relationship between participants who use private cars or trains for long distance travel and familiarity with AVs. As Table 5-10 illustrates, these respondents were more familiar with AVs than those who use other modes of transport: 30.14% of the 36% of participants who use private car have heard of AVs and 24.66% of the 34% who use trains. By contrast, respondents who said they were not sure are more likely to use trains than private car, 5.48% and 1.83%, respectively.

Table 5-10. Cross-tabulation of respondents' familiarity with AVs and preferred travel mode for long distances (Author, 2021).

Had you ever heard of AVs, driverless or automated cars before taking part in this survey?	**How do you usually travel between cities or over long distances?**	
	Private car (Out of 36%) Figure 5-4	**Train** (Out of 34%) Figure 5-4
Yes	30.14%	24.66%

No	3.65%	4.11%
Not Sure	1.83%	5.48%

5.5.3.2. General attitudes towards AVs

The next question provided respondents with a definition of AVs and asked about their feelings towards them in general. A seven-point Likert-type scale was provided (from Extremely negative to Extremely positive) and an "Other" option was also provided. The results are shown in Figure 5-8.

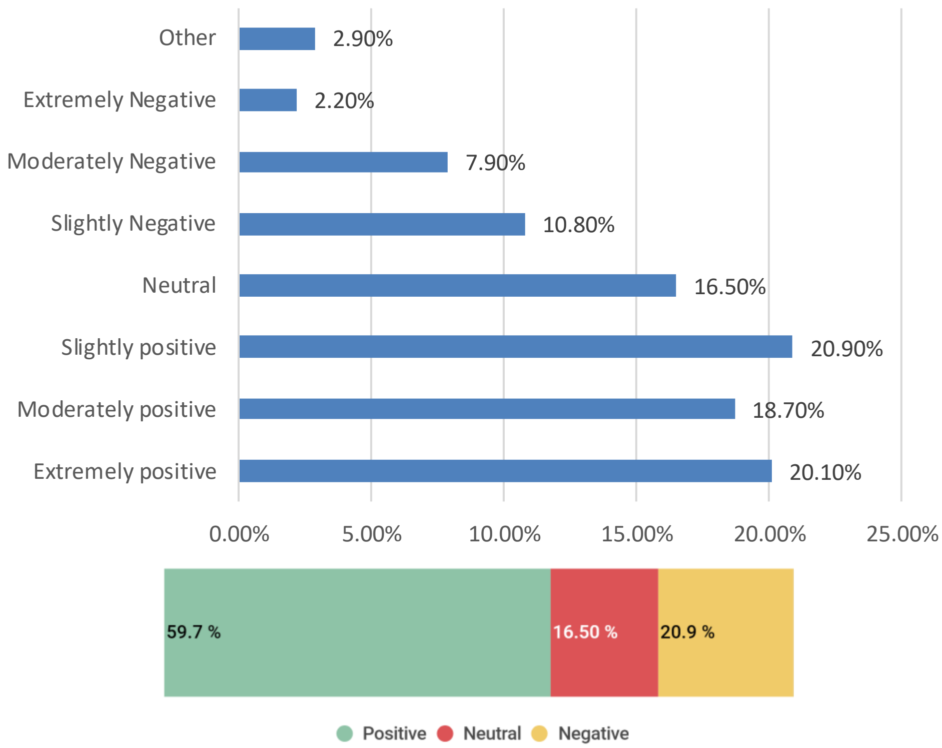


Figure 5-8. Participants' responses to Q5: What is your thought about Autonomous Vehicles? (Author, 2021)

Overall, 59.7% of the respondents reported feeling positive about the technology compared to 20.9% who were negative and 16.50% who were neutral. There was a significant disparity between "extremely positive" (20.10%) and "extremely negative" (2.20%). 2.90% of respondents selected the "Other" and went on to explain why they did not select one of the other options. Comments included (1) doubts about the efficiency and precision of AV technology: *"I am not sure of their efficiency and precision and whether all possibilities are fed into their used system."* (Participant 72); (2) sustainability issues: *"they are potentially a solution to the exhaustive drain on fossilised fuels"* (Participant 100); (3) lack of trust: *"not sure if I can rely on/trust more a machine or human"* (Participant 107); and, (4) lack of sufficient evidence: *"Indecisive, I need [to] see Pro's and Con's"* (Participant 130).

Analysis was then conducted to identify whether familiarity with AVs promotes positive or negative feelings about them. Table 5-11 and Figure 5-9 break down the relationship between respondents' being familiar with the technology and their general attitudes towards AVs.

As the results demonstrate, 47.15% of participants who had already heard of AVs felt positive about them (slightly, moderately, or extremely) compared to 17.86% who felt negative (slightly, moderately or extremely). The former represents 62.1% of the overall participants who had heard of AVs and the latter represents 22.6% of them. Of those participants who had never heard of AVs, 6.73% were positive while 2.14% were negative, and 5% of those who were not sure if they had heard of AVs felt positive towards them compared to 10% who felt negative. Of those respondents who felt neutral regarding AVs, 10.71% had heard of AVs while 1.43% had not and 4.29% were not sure.

Table 5-11. Cross-tabulation of respondents' familiarity with AVs and their general thoughts about them (Q4 vs Q5) (Author, 2021).

Overall attitude towards Autonomous Vehicles	**Had you heard of autonomous, driverless or automated cars before taking part in this survey?**		
	Yes	No	Not sure
Extremely positive	17.86%	0.71%	1.43%
Moderately positive	15.00%	1.43%	1.43%
Slightly positive	14.29%	4.29%	2.14%
Neutral	10.71%	1.43%	4.29%

Slightly Negative	8.57%	2.14%	0.00%
Moderately Negative	7.86%	0.00%	0.00%
Extremely Negative	1.43%	0.00%	0.71%
Other	2.14%	0.71%	0.00%
Total	79%	11%	10%

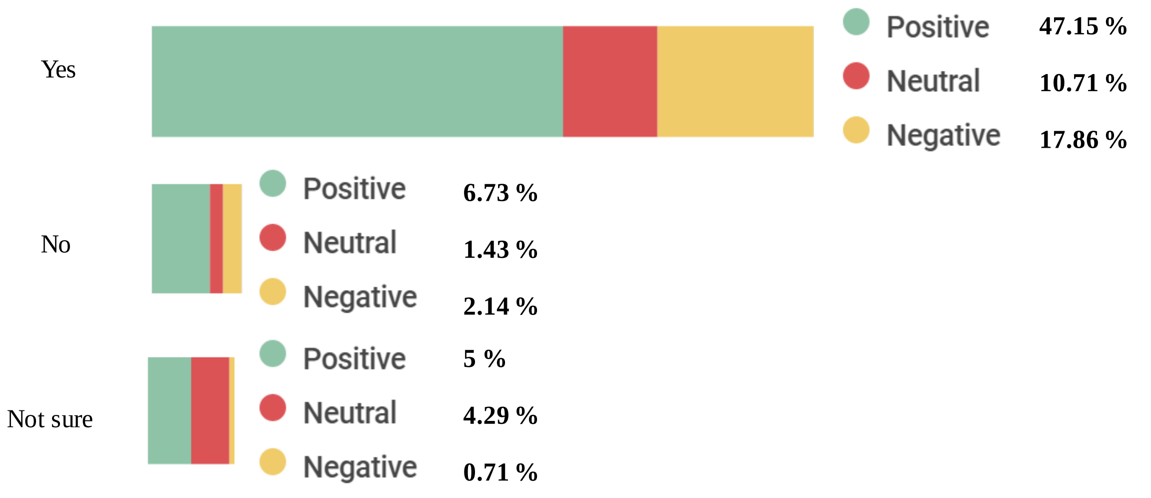


Figure 5-9. Participants' overall attitudes towards AVs based on familiarity with them (Author, 2021).

Comparing the percentages of respondents who expressed a negative opinion about AVs, it is clear that respondents who were already familiar with AVs reported higher negative attitudes than respondents who were not familiar with them. Therefore, being familiar with the technology does not necessarily lead to positive feelings about AVs. However, the moot question here is why 17.86% of the respondents who were familiar with AVs felt negative about them. As user acceptance is a highly significant factor in AV adoption, it is crucial to understand the reasons behind this. As a result, a correlation analysis was carried out to define the degree of association between the type of car participants own/use and their overall attitudes towards AVs. Two car types were selected (Saloon and SUV) and the results are shown in Table 5-12. The reason for selecting these two types of cars s because of the significance level.

Table 5-12. Correlation between feeling towards AVs and type of care owned (Author, 2021).

		CAR TYPE_Saloon	CAR TYPE sports utility vehicle (SUV)
Q5_THOUGHT_ABOUT_AVS_Slightly positive	Correlation Coefficient	.259**	-.179*
	Sig. (2-tailed)	.002	.035
	N	139	139

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

5.5.3.3. Overall attitudes and desire to own or share AVs

Respondents were then asked if they would like to own or share an AV in the future, and invited to select a response from four options (Own, Share, Neither or Other). The results are shown in Figure 5-10.

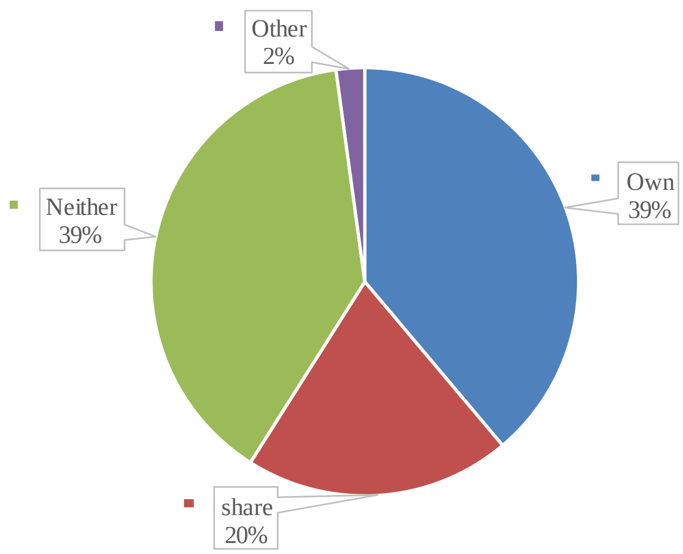


Figure 5-10. Distribution of participants' responses to Q6: Would you like to own or share an Autonomous car?(Author, 2019)

As Figure 5-10 demonstrates, 39% of the respondents expressed interest in owning an AV compared to 20% who opted for sharing the upcoming technology. However, more than the third of the respondents (39%) said they were not interested in either option. 2.2% selected the "Other" option and provided a number of comments about owning or sharing an AV. One thought that decisions about owning or sharing the technology would depend on various reasons, notably where the person is living (rural or urban): *"This would be in an urban* *context only? What if you live in a rural community"* (Participant 100). The same participant added that it would also depend on the number of cars that could be owned: "*Would you need to own two or more cars?"* Other reasons mentioned included safety, personal experience, and learning about them in advance.

Cross-tabulation analysis was then conducted to identify if there was a relationship between the respondents who were positive, negative or neutral about AVs and their readiness to share or own an autonomous car. The results are shown in Table 5-13.

Table 5-13. Cross-tabulation of the respondents' general attitudes towards AVs and their willingness to own or share one (Q5 vs Q6) (Author, 2021).

Overall attitude towards AVs	**Would you like to own or share an autonomous car?**			
	Own	**Share**	**Neither**	**Total**
Positive	30.72%	15.71%	12.86%	59.29%
Neutral	4.29%	2.86%	9.29%	16.44%
Negative	3.57%	0.71%	15.00%	19.28%
Totals	**39%**	**20%**	**39%**	

As the figure demonstrates, respondents who felt positive about AVs were more likely to want to own one. 30.72% of positive respondents opted for ownership, which is roughly 79% of the total respondents who opted to own an AV and 52% of overall respondents with a positive opinion of AVs. By contrast. 15.71% of positive respondents chose to share, representing 78% of total respondents who opted to share an AV and 27% of the overall respondents with a favourable opinion of AVs. 12.86% of positive respondents chose neither to own nor share AVs, representing 21% of the total respondents with a positive opinion of AVs and 33% of the total respondents who chose neither to own nor share. Overall, 52% of positive respondents opted to own, 27% to share and 21% to neither own nor share.

Respondents who felt neutral to the upcoming technology were more likely to opt for neither ownership or sharing; 9.29% selected this option, which represents 57% of the total respondents that chose "Neutral" and 24% of those who selected "Neither". 4.29% of neutral respondents expressed a desire to own an AV, constituting 26% of the total respondents that chose "Neutral" and 11% of overall respondents who opted for "Neither". 2.86% of neutral respondents preferred to share, which represents 17% of the total respondents that chose "Neutral" and 14% of those who expressed a preference to share.

Respondents who expressed negative thoughts about AVs were less likely to want to share or own one. 15% of negative respondents opted neither to own or share AVs, representing 78% of total negative respondents and 38% of total respondents who selected "Neither". Only 0.71% preferred to share, representing 3.5% of the total respondents who opted to share and 3.6% of the total negative respondents. 3.57% chose to own an AV, which is 9% of the total respondents who opted to own an AV and 19% of the total negative respondents.

A correlation test was then conducted to explore these results in more detail. Table 5-14 shows the results and provides a summary of the correlation coefficient and the significance level between the respondents' attitudes towards AVs and their interest in owning or sharing an AV.

Table 5-14. Correlation between attitudes to AVs and willingness to own or share one AV (Author, 2021)

	Attitudes Towards AVs		Neither	Share	Own
Spearman's rho	Extremely Negative	Correlation Coefficient	.187*	-.074	-.119
		Sig. (2-tailed)	.027	.385	.161
		No.	140	140	140
	Moderately Negative	Correlation Coefficient	.259**	-.146	-.181*
		Sig. (2-tailed)	.002	.085	.033
		No.	140	140	140
	Slightly Negative	Correlation Coefficient	.152	-.115	-.042
		Sig. (2-tailed)	.072	.174	.620

		No.	140	140	140
	Neutral	Correlation Coefficient	.164	-.029	-.120
		Sig. (2-tailed)	.054	.735	.158
		No.	140	140	140
	Slightly positive	Correlation Coefficient	.066	.053	-.086
		Sig. (2-tailed)	.441	.535	.310
		No.	140	140	140
	Moderately positive	Correlation Coefficient	-.265**	.220**	.105
		Sig. (2-tailed)	.002	.009	.218
		No.	140	140	140
	Extremely positive	Correlation Coefficient	-.333**	.009	.347**
		Sig. (2-tailed)	.000	.918	.000
		No.	140	140	140

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The results in Table 5-14 demonstrate that there is a relationship between the participants' attitudes towards AVs and their desire to own or share one; however, this varies from weak to moderate. For instance, a moderate correlation can be captured between the participants who expressed extremely positive thoughts and the desire to possess an AV (r=.347, p=.000).

5.6. Participants' Views of AVs' Expected Benefits

Respondents were also asked which of the anticipated benefits of AVs they found most attractive and how they thought they would use the extra time they gained by being driven instead of having to drive themselves.

5.6.1. Attractiveness of AVs' expected benefits

(Hyatt, 2017) argues that the adoption of AVs will bring about the most substantial transition in our societies and cities since the internet emerged, and a number of benefits have been associated with AVs. These include increases in road safety and comfort (Banchiri, 2016; NHTSA, 2013), reduced traffic congestion, pollution, fuel consumption, and enhanced mobility for disabled and older people. Table 5-15 lists the main anticipated benefits identified in recent studies.

Table 5-15. Anticipated benefits found in the literature on AVs (Author, 2021).

Anticipated Benefits of AVs	Studies
Innovative freight delivery	Alessandrini et al. (2015)
Insurance cost reduction	Agarwal, Kumar and Zimmerman (2019) Wadud (2017)
Efficiency of road transport and a number of service categories	Alfonso et al. (2018)
Control of traffic flow	Liu et al. (2019a) Stern et al. (2018)
Maximise intersection capacity and minimise its bottlenecks	Sun, Zheng and Liu (2017)
Comfort and entertainment services	Atzori et al. (2018) Panagiotopoulos and Dimitrakopoulos (2018)
Reduced congestions and increased accessibility	Joiner (2018) The House of Lords Science and Technology Committee (2017)
Energy efficiency	Vahidi and Sciarretta (2018)
Fuel consumption reduction through platooning and "Right-sizing" of vehicles	Simoni et al. (2018) Vahidi and Sciarretta (2018) Zhao et al. (2018) Wadud, MacKenzie and Leiby (2016)
Make travelling by car more attractive	Gruel and Stanford (2016)
Offer mobility to people unable to drive	Alessandrini et al. (2015) Fagnant and Kockelman (2015)
Tourism extension	Cohen and Hopkins (2019)
Economic and social	Bechtsis et al. (2018) Bichiou and Rakha (2018)
Expand new markets and more software and hardware companies to be developed	Bamonte (2013)
Travel speed increase	Kröger, Kuhnimhof and Trommer (2018)

Thus, the next question explored participants' opinions regarding the anticipated benefits of AVs, asking them to identify the benefits which would motivate them to use AVs from a list of 10 plus an "Other" option. Respondents were asked to select no more than three options. Table 5-16 and Figure 5-11 illustrate the frequencies and percentages of their responses.

Table 5-16. Respondents' views of the most attractive benefits of AVs (Author, 2021)

Anticipated Benefits	Frequencies			Valid percentage %		
	Yes	*No*	*Total*	*Yes*	*No*	*Total*
Safety and reduced crashes	56	84	140	40	60	100
New service	30	110		21.4	78.6	

Reduced driver stress	65	75	46.4	53.6
Effectiveness	23	117	16.4	83.6
Sustainability	33	107	23.6	76.4
Ideas for sharing	6	134	4.3	95.7
Reduced congestion	24	116	17.1	82.9
Efficient parking	38	102	27.1	72.9
Independent mobility	35	105	25	75
Great opportunities for deliveries	10	130	7.1	92.9

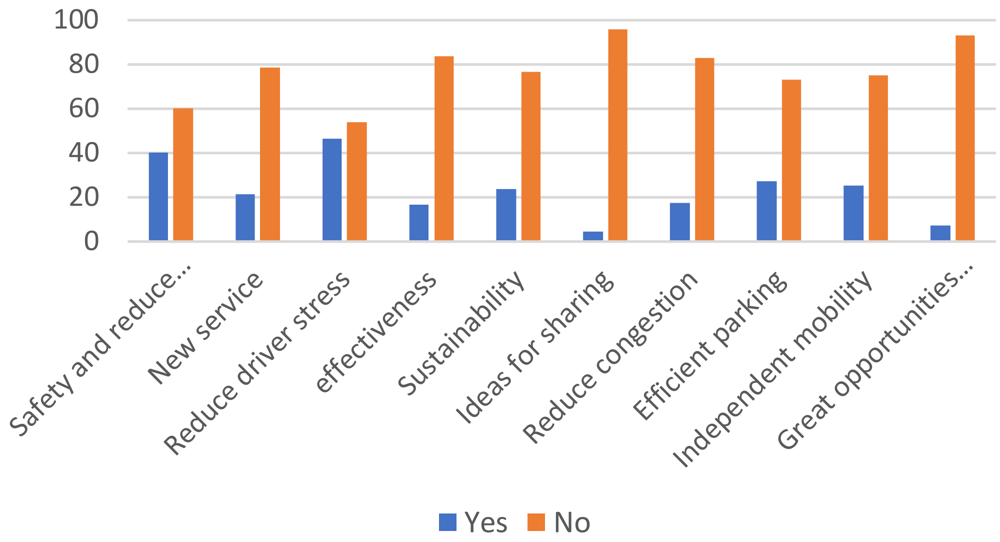


Figure 5-11. Participants' responses to Q7: You would like to use an Autonomous car because of...? (Author, 2021)

Although many scholars believe that the highest anticipated benefit of AVs is increased safety, the most attractive benefit for the respondents is reduced driver stress; 46.4% selected this option while 40% selected safety and reduced crashes. The third most popular benefit was "efficient parking" (27.1%); this might be explained by the fact that UK motorists spend around four days (91 hours) a year trying to find a parking space (British Parking association, 2016). Thus, this benefit is thought to be important when adopting AVs because it will help to decrease time spent looking for parking spaces.

Independent mobility was the fourth most popular choice (25%). This is supported by studies such as (Agarwal et al., 2019; Alessandrini et al., 2015) who anticipated that AVs would provide enhanced accessibility and mobility for disabled and older people and may also help children go to school without their parents having to drive them there. Sustainability (23.6%), reduced congestion (17.1%), and effectiveness (16.4%) also attracted some interest; however, benefits such as "great opportunities for deliveries" and "ideas for sharing" were the least favoured anticipated benefits at 7.1% and 4.3% respectively. Further benefits of AVs are expected to emerge when full adoption in cities is achieved.

5.6.2. Preferred activities while being driven inside AVs

Since an AV drives itself, users are liberated from the task of driving. This provides an opportunity to do other things, such as work, sleep or other entertainment activities. Hence, participants were asked how would they benefit from the time gained by being driven instead of driving. A list of seven activities was provided along with an "Other" option. Table 5-17 illustrates the participants' responses.

Table 5-17. Activities participants would choose inside an AV instead of driving (Author, 2021).

Activities	**Frequencies**			**Valid Percentage**		
	Yes	No	Total	Yes	No	Total
Sleeping	53	87	140	37.9	62.1	100
Reading	56	84		40	60	
Working	47	93		33.6	66.4	
Meeting	15	125		10.7	89.3	
Watching TV	28	112		20	80	
Playing games	20	120		14.3	85.7	
Simply enjoying the outside views	77	63		55	45	

As the table demonstrates, the most popular activity people would do in an AV is simply enjoying the outside views. 55% of the respondents expressed an interest in this activity, followed by 40% of people who would prefer to benefit from this time by reading. Sleeping was the third favourite activity, selected by 37.9% of participants. This percentage can be linked to people's lack of readiness to accept the safety of this technology fully. Working was the next most popular activity, with 33.9% of participants choosing to work while they are being driven.

Although the AVs capabilities are expected to allow users’ to participate in recreational activities, such as watching television or playing games, these activities did not particularly appeal to the participants, and were selected by just 20% and 14.3%, respectively. This lack of interest in entertainment activities can perhaps be explained by users' feelings and distrust in automation, as (Joiner, 2018; Winter et al., 2018) stressed that much of people’s unwillingness to ride in AVs is because of those feelings. The least popular activity was meetings (15%). A number of comments were made via the "Other" option, and these can be divided into main three themes: 1) some participants expressed distrust regarding AVs and commented that they did not want to use them; 2) some suggested other activities, such as social meetings and catching up with social media; and 3) some participants did not think there would be any difference between riding in an AV or a conventional car.

5.7. Big Data and Participants’ Willingness to Share Personal Data

AVs are expected to process considerable amounts of data that can be generated through V2X communication. Part of this communication will involve private information about users, such as location, origin and destination data and images and videos. As a result, participants were asked about their willingness to share personal data in these circumstances.

5.7.1. Willingness to share data

Participants were first advised that AVs would be collecting data about them and asked if to they would be keen to share their data for purposes such as healthcare, insurance, council services etc. Respondents were asked to indicate their agreement on a six-point scale (ranging from moderately agree to strongly disagree, as it was assumed no respondents would strongly agree). As Figure 5-12 demonstrates, 25% of respondents strongly disagreed with the idea of sharing their data in this way, compared to 17.9% who moderately agree. A further 24.30% slightly agreed; however, overall, around half of the sample disagreed with the idea of sharing their data. On the other hand, 11.4% of participants said they neither agreed nor disagreed. This suggests that concerns around data sharing is a significant barrier in terms of user acceptance and behaviour.

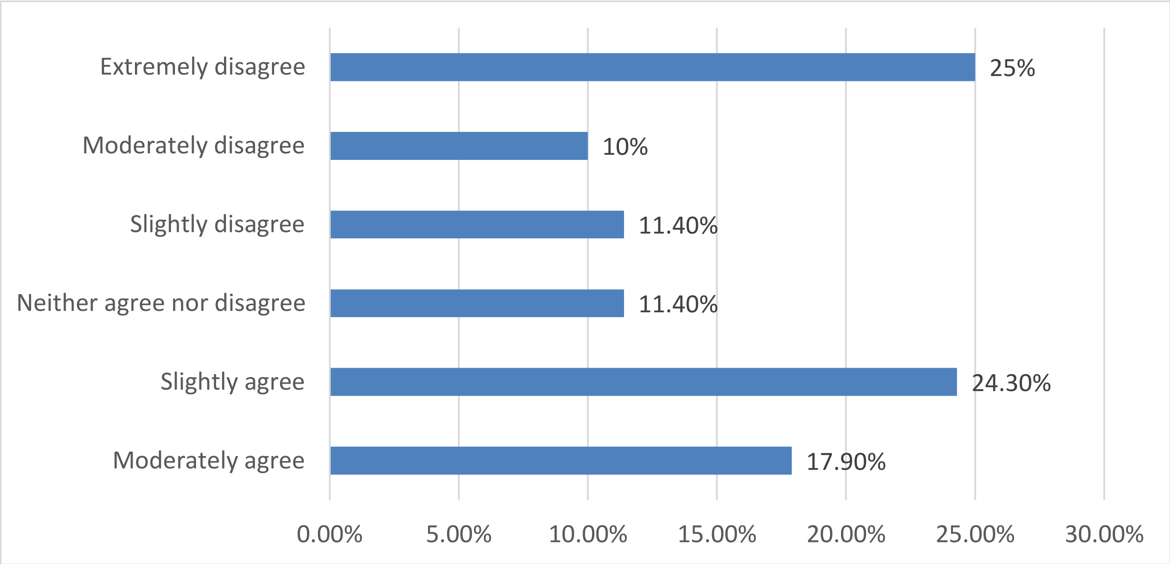


Figure 5-12. Participants' willingess to share personal data during AV travel (Author, 2021)

5.7.2. Type of data users are willing to share

In order to explore participants' attitudes towards data sharing in more detail, the next question asked if they would be willing to share specific types of data. Seven data-types were provided along with an "Other" option. The results are shown in Figure 5-13.

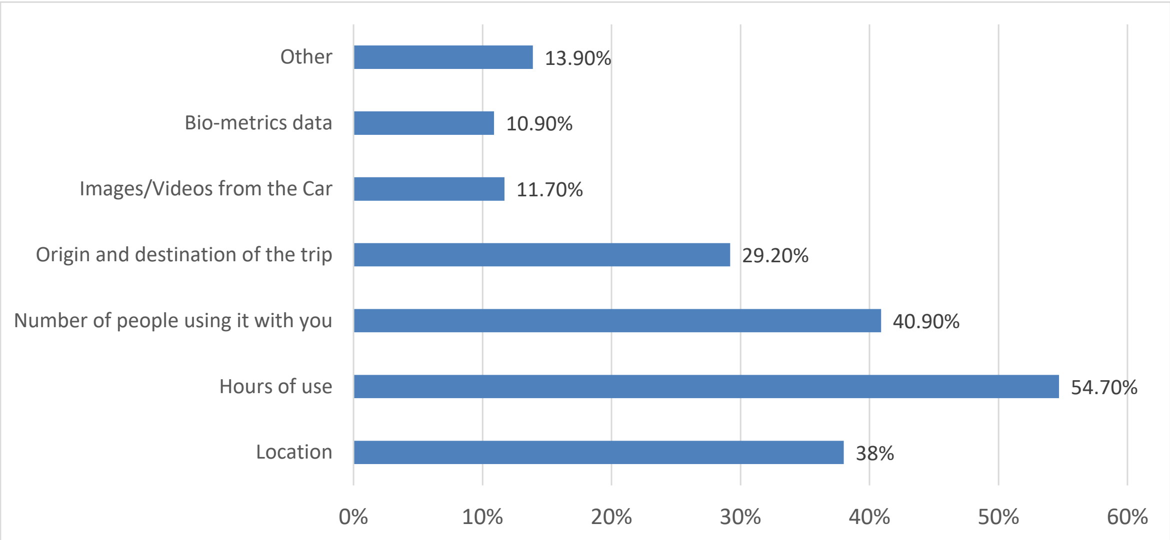


Figure 5-13. Participants' response to Q9: What kind of data are you willing to share? (Author, 2021)

As the figure shows, 54.7% of participants agreed to share their hours of use and 38% agreed to share their location. Similarly, 40.9% agreed to share the number of people using the vehicle and 29.2% the origin and destination of the trip. This may be because this this type of information is not considered too personal for these users to share. However, they were much less keen to share images and videos from the car (11.7%) and biometric data (10.9%). Nevertheless, several participants mentioned in the "Other" option that they were willing to share their data, even personal data, in the event of an accident.

5.8. Attributing Responsibility for Accidents

As users of AVs are not expected to be in control of the vehicle, the question of who should be held responsible in case of an accident has yet to be resolved. In order to explore their views, participants were asked who they thought should be held responsible: (i) Manufacturers, (ii) City Planners, (iii) Owners, (iv) Insurance companies, or (v) all of the above. An "Other" option was also provided. The results are shown in Figure 5-14.

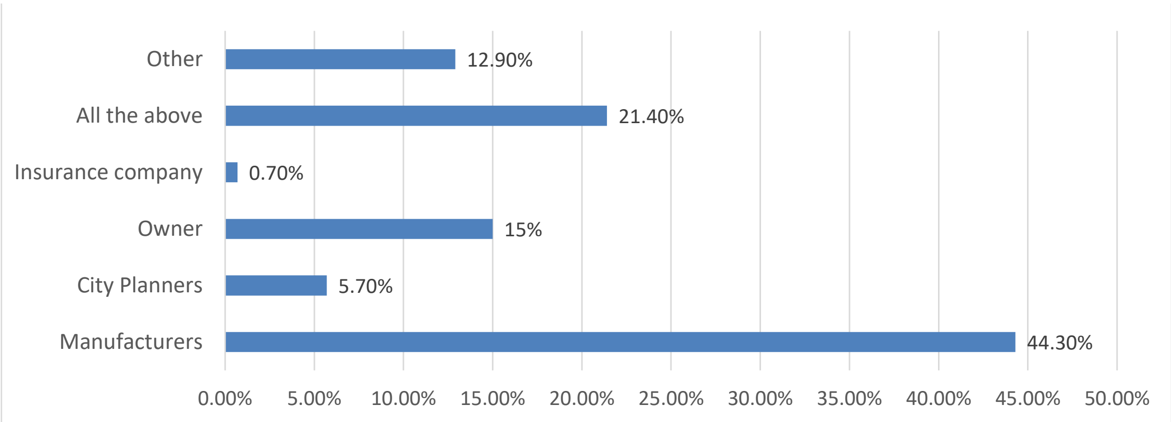


Figure 5-14. Participants' views of who is to blame in case of an accident (Author, 2021)

As the figure shows, 44.3% of participants believe that manufacturers should be blamed, with just 0.70% holding insurance companies responsible. 15% think that the owner should be blamed, while 5.7% assume that city planners should be held responsible. However, 21.4% of participants said all the parties should be held responsible. and also depends on the accident situation and circumstances.

5.9. Concerns About the Disappearance of Sports Vehicles

The belief that manual driving will disappear or be banned after the full adoption of AVs has raised concerns about the disappearance of sports vehicles and the enjoyment of driving. In order to examine these concerns, participants were asked how concerned they were about the disappearance of sports vehicles and the enjoyment of driving. The results are shown in Figure 5-15. Overall, approximately 55% of respondents were concerned about the potential disappearance of sports vehicles, and 21.7% were extremely concerned. However, 18.1% were not concerned at all, and 25.4% stated that they were neutral.

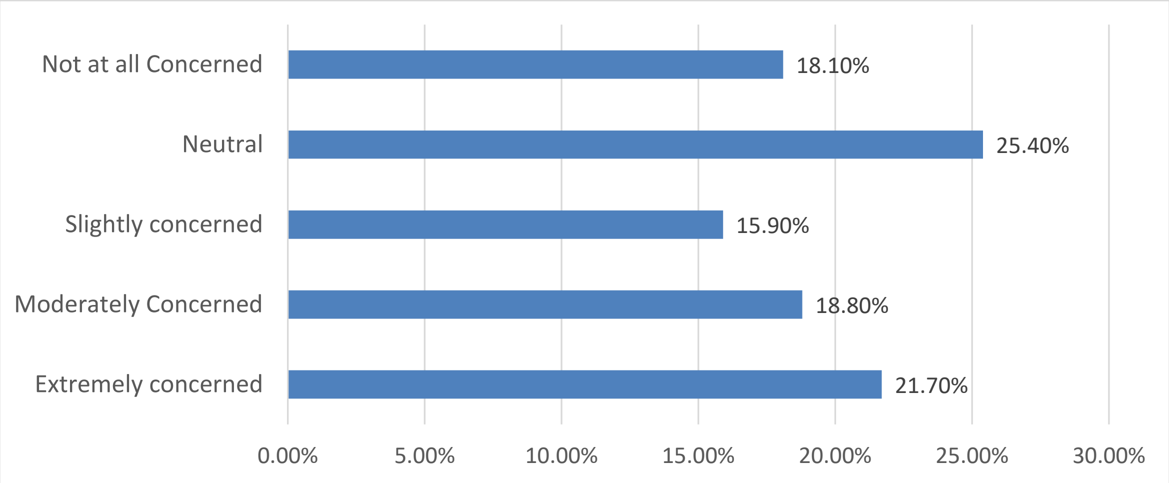


Figure 5-15. Participants' responses to Q11: How concerned are you about the disappearance of Sports Vehicles and the enjoyment of driving when AVs are fully adopted? (Author, 2021)

5.10. General Views About Current Barriers to AV Adoption

Participants were then asked what they thought the main barriers to AV adoption were. A list of the barriers identified in the literature review was provided, along with an "Other" option, as shown in Figure 5-16.

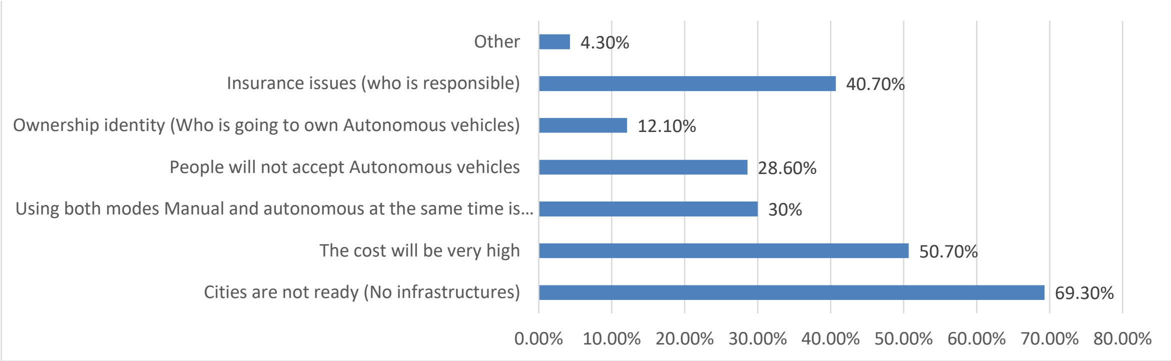


Figure 5-16. Participants' responses to Q13: What do you think are the barriers to adopting AVs? (Author, 2021)

As can be seen, the main barriers from the respondents' perspectives are the lack of infrastructure in cities (69.3%) and high cost (50.7%). In addition, 40.7% identified insurance issues (who is responsible) and 30% consider that using both manual and automated driving modes could be a barrier. 28.6% of respondents thought that public acceptance of AVs would be a significant barrier too. Other barriers were suggested by users (In the "Other" option) such as safety, lack of information about AVs, Technology is not mature, and people distrust technology before testing them.

The data gathered from the responses to the survey questions was then used to test a series of hypotheses to explore users' behaviour regarding AVs more fully. These hypotheses were presented in Table 5-1 and Table 5-2, and the analysis and results are discussed in detail in the next section.

5.11. Hypotheses Testing and Analysis

In order to explore the participants' responses in more detail, a number of hypotheses were formulated and tested. These addressed the following areas:

a) preferred mode(s) of transport and the desire to own or share an AV;

b) type of car currently owned or used and concerns about the disappearance of sports vehicles;

c) prior knowledge of AVs and positive, negative or neutral attitudes towards them;

d) prior knowledge of AVs, attitudes towards them, desire to own or share one, and willingness to share personal data;

e) preferred mode of transport, desire to own or share an AV, and who should be blamed in the event of an accident;

f) type of car currently owned or used and desire to own an AV in the future

The hypotheses and sub-hypotheses which were tested, the analysis conducted, and the results of the analysis are presented below.

5.11.1. Hypothesis 1

Testing this hypothesis involved testing four sub-hypotheses concerning the preferred mode of transport in the city or between cities (short and long distances) and the desire to either share or own an AV. The structure of this hypothesis is shown in Table 5-18.

Table 5-18. Hypothesis 1 (Author, 2021)

Hypotheses (Alternative)	**Sub-Hypotheses**
Hypothesis 1 *Participants mode of transport (either in or between cities) and the expected behaviour when using AVs (share/own*	**In the city (Questions 1 & 6)** **a**. Participants who use public transport (e.g. Taxi, Bus, Tram, Train, Carpooling) are likely to want to share an AV. **b**. Participants who use private cars are expected to want to own an AV. **Between cities (Questions 2 & 6)** **c**. Participants who use Public transport (e.g. Taxi, Coach, Train, Carpooling) are likely to want to share an AV. **d**. Participants who use private cars are expected to want to own an AV.

Cross-tabulation analysis was conducted to describe the relationship between the variables. Logistic Regression was also applied as it is the most suitable regression analysis to conduct when the dependent variable is dichotomous (binary) (LaValley, 2008; Peng & So, 2002). In addition, (Tabachnick & Fidell, 2013) believe there is an increase in social researchers employing logistic regression as a viable substitutional technique for linear regression.

5.11.1.1. In the City

a. *Participants who use Public transport (e.g. Taxi, Bus, Tram, Train, Carpooling) around the city are more likely to want to share an AV.*

Table 5-19 highlights the association through cross-tabulation between use of public transportation (taxi, bus, tram, train and carpooling) and respondents' desire to share an AV in the future. As can be observed, carpooling and trams are the highest modes associated with sharing, with 52.85% and 29.73%, respectively.

Table 5-19. Cross-tabulation between public transportation mode use and desire to share AVs (in the city) (Author, 2021).

Would you like to own or share an AV?	**Public transportation mode**					
	Taxi	Bus	Tram	Train	Carpooling	**Totals**
Share	1.85%	5.19%	3.33%	0.74%	0.37%	20.10%
% of total participants using this mode	8.2%	23%	11.20%	3%	0.70%	
% of people who wish to share out of the total number of participants using this mode	22.69%	22.56%	29.73%	24.66%	52.85%	

To perform logistic regression and explain the positive relationship between the dependent binary variable "share an AV" and the nominal variable "public transportation", the following assumptions were checked:

- The dependent variable should be dichotomous.
- There should be no outliers in the data.

The analysis of the hypothesis focused on the factor of "using public transportation" and whether it has affects the "desire of an individual to share an AV". In other words, whether people who currently use public transportation can be expected to want to share AVs. Therefore, using logistic regression hypothesis, "a" can be represented as follows:

H0: The independent variable does not significantly predict the dependent variable.

Ha0: People who are using public transportation to move around the city **does not significantly** predict that people will share AVs.

H1: The independent variable significantly predicts the dependent variable.

Ha1: People who are using public transportation to move around the city **significantly** predict that people will share AVs.

As can be seen in Table 5-20, the logistic regression model is statistically significant, ($\chi2$ = 5.700 and p = 0.017 < 0.05). The model explains 35.9% (Nagelkerke R2 = 0.359) of the variance in sharing an AV has classified 56.6% of cases.

Table 5-20. Logistic regression results: Hypothesis 1a (Author, 2021).

Model	B	Sig.	Exp(B)	Nagelkerke R Square	df	Chi-square	Sig.	Percentage Correct
Public	0.481	0.023	1.617	0.359	1	5.700	0.017	56.6

Test value: alpha=0.05

The p-value of the predictor "using public transportation" Sig = 0.023 < 0.05, so we reject the null hypothesis and accept the alternative hypothesis. Therefore, the independent variable predicts the dependent variable significantly, and we can explain the positive relationship between the two variables. This is to say that for every one-level increase in using public transportation around the city, a 1.617 growth in the log-odds of sharing an AV is expected.

To see whether the participants' information influences this positive relationship or not, the logistic regression test was rerun taking into consideration the participant information (Age, Gender, Occupation, Distance between home and place of work or study, Marital status and Level of education). The results are shown in Table 5-21.

Table 5-21. Logistic regression of participants' information and sharing AVs: Hypothesis 1a (Author, 2021).

Participants' information	B	S.E.	Wald	df	Sig.	Exp(B)
Age	-	-	6,24	6	0,397	-
Gender (1)	-1,626	0,5	10,601	1	0,001	0,197
Occupation	-	-	3,558	5	0,615	-
Distance between home and work or study place	-	-	8,294	5	0,141	-
Marital status	-	-	0,431	3	0,934	-
Level of education	-	-	5,415	4	0,247	-

As Table 5-21 shows, the variables mentioned above are not statistically significant in the logistic regression, except for gender. The p-values of the variables: Age, Gender, Occupation, Distance between home and place of work or study, Marital status and Level of education are all greater than 0.05. On the other hand, the gender variable is statistically significant (sig = 0.001). Therefore, the participants' gender has a positive relationship with their desire to share AVs. As per Table 5-21, the gender Female is codified by 1, which means that females are (1/0.197) 5.07 times more likely to want to share an AV than males.

b. *Participants who use Private cars around the city are more likely to want to own an AV.*

Table 5-22 illustrates the associations between the use of a private car and the desire to share an AV in the future. As can be seen, 10.37% of the participants who use a private vehicle wish to own an AV. They constitute 56.99% of the total participants who use private cars and wish to own an AV.

Table 5-22. Cross-tabulation between private car use (in the city) and the desire to own AVs (Author, 2021).

Would you like to own or share an AV?	**How do you usually travel (move) around the city?**
	Private Car
Own	10.37%
% of total participants using this mode	19.3%
% of total participants who are willing to own an AV	38.8%
% of participants who want to own an AV out of total participants using this mode	56.99%

In respect of the logistic regression, the same assumptions were checked:

- The dependent variable should be dichotomous.
- There should be no outliers in the data.

The above assumptions enabled the logistic regression to be performed to explain the relationship between the dependent binary variable: "Own an AV" and the nominal variable: "Private car use". That is to say that the hypothesis testing focused on whether people who currently own private cars are more likely to want to possess an AV in the future. Therefore, Hypothesis b was broken down as follows:

H0: The independent variable does not significantly predict the dependent variable.

Ha0: People who are using their private car to move around the city **does not significantly** predict that people will own AVs.

H1: The independent variable significantly predicts the dependent variable.

Ha1: People who are using their private car to move around the city **significantly** predicts that people will own AVs.

As can be seen in Table 5-23, the logistic regression model is statistically significant, ($\chi2$= 7.426 and p = 0.006 < 0.05). The model explained only 7.2% (Nagelkerke R2 = 0.072) of the variance in owning an AV and precisely classified 64% of cases.

Table 5-23. Logistic regression results: Hypothesis 1b (Author, 2021)

Model	B	Sig.	Exp(B)	Nagelkerke R Square	df	Chi-square	Sig.	Percentage Correct
Private car	0.993	0.007	2.700	0.072	1	7.426	0.006	64

Test value: alpha=0.05

The p-value of the predictor "using a private car" Sig = 0.007 < 0.05, so we reject the null hypothesis and accept the alternative hypothesis. Therefore, the independent variable predicts the dependent variable significantly, and we can explain the positive relationship between the two variables. In other words, for every one-level increase in using a private car in/around the city, a growth of 2.700 is expected in the log-odds of owning an AV in the future.

As with hypothesis "a", it is critical to analyse to what extent the participants' information affects this positive relationship. Thus, the logistic regression test was rerun, taking into consideration the participant information (Age, Gender, Occupation, Distance between home and place of work or study, Marital status and Level of education). The gender Female was codified by 1, which means that females are (1/0.168) 6.25 times more likely to want to own an AV than males (See Table 5-24).

Table 5-24. Logistic regression of participants' information and owning AVs: Hypothesis 1b (Author, 2021).

Participants' information	B	S.E.	Wald	df	Sig.	Exp(B)
Age	-	-	6.219	6	0,399	-
Gender (1)	-1,785	0,505	12.491	1	0,000	0,168
Occupation	-	-	2.412	5	0,790	-
Distance between home and work or study place	-	-	6.988	5	0,222	-
Marital status	-	-	0,146	3	0,543	-
Level of education?	-	-	5,148	4	0,272	-

5.11.1.2. Between Cities

c. *Participants who use Public transport (e.g. Taxi, Coach, Train, Carpooling) are more likely to want to share an AV.*

Table 5-25 shows the cross-tabulation between the "public transport mode" and "willingness to share an AV". Interestingly, participants who use Taxi as the preferred mode to move between cities showed no interest in sharing AVs. By contrast, participants who use carpooling are most likely to want to share AVs amongst the different methods to move between cities. Besides, participants who use coach and train to move are expected to share an AV with 22% and 20% respectively.

Table 5-25. Cross-tabulation between public transportation mode use and desire to share AVs (Between cities or over long distances) (Author, 2021).

Would you like to own or share an AV?	**How do you usually travel (move) between cities or over long distances?**				**Totals**
	Taxi	*Coach*	*Train*	*Carpooling*	
Share	0.00%	4.57%	6.85%	1.83%	20.10%
% of total participants using this mode	3.20%	21.1%	34.4%	3.7%	
% of people who want to share out of the total participants using mode	0.00%	21.65%	19.91%	49.45%	

As with the sub-hypotheses set for "In the city", logistic regression was applied to predict future AV use "between cities" and explain the positive relationship between the dependent binary variable "share an Autonomous Vehicle" and the nominal variable "public transportation" between the cities or over long distances.

The hypotheses of the logistic regression were:

H0: The independent variable does not significantly predict the dependent.

Ha0: People who are using public transportation to move between cities (long-distance) **do not significantly** predict that people will share AVs.

H1: The independent variable significantly predicts the dependent variable.

Ha1: People who are using public transportation to move between cities (long-distance) **significantly** predict that people will share AVs.

The results are given in Table 5-26 below:

Table 5-26. Logistic regression results: Hypothesis 1c (Author, 2021)

Model	B	Sig.	Exp(B)	Nagelkerke R Square	df	Chi-square	Sig.	Percentage Correct
Public	0.060	0.781	1.062	0.001	1	0.077	0.781	59.0

Test value: alpha = 0.05

As the table shows, the logistic regression model is not statistically significant, (χ^2 = 0.077 and p = 0.781 > 0.05). Besides, the model explained only 0.1% (Nagelkerke R^2 = 0.001) of the variance in sharing an AV and correctly classified 59% of cases. The p-value of the predictor "using public transportation" Sig = 0.781 > 0.05, so the null hypothesis that the independent variable does not significantly predict the dependent variable is accepted.

Consequently, based on the cross-tabulation and logistic regression analysis, there is no significant positive relationship between using public transportation between the cities or over long distances and sharing an AV.

d. *Participants who use Private cars between the cities or over long distances are more likely to want to own an AV.*

Table 5-27 provides the cross-tabulation between "using Private cars between cities" and "Willingness to own an AV*"*. As the table demonstrates, only 14.16% of people who use private cars to travel long distances opted to own an AV in the future. These represent 36.49% of the total participants who wish to own an AV.

Table 5-27. Cross-tabulation between private car use mode use and desire to own AVs (Between cities or over long distances) (Author, 2021).

Would you like to own or share an AV?	**How do you usually travel (move) between the cities or long distances?**
	Private Car
Own	14.16%
% of total participants using this mode	35.8%
% of total participants willing to own an AV	38.8%
% of participants who want to own an AV out of the total participants using this mode	36.49%

Logistic Regression was again applied to explain the relationship between the dependent binary variable "own an Autonomous Vehicle" and the nominal variable "use Private cars." The results are given in Table 5-28 below.

The hypotheses of the logistic regression were:

H0: The independent variable does not significantly predict the dependent variable.

Ha0: People who are using their private car to move between cities (long-distance) **does not significantly** predict that people will Own AVs.

H1: The independent variable significantly predicts the dependent variable.

Ha1: People who are using their private car to move between cities (long-distance) **significantly** predicts that people will own AVs.

Table 5-28. Logistic regression results: Hypothesis 1d (Author, 2021)

Model	B	Sig.	Exp(B)	Nagelkerke R Square	df	Chi-square	Sig.	Percentage Correct
Private car	0.018	0.960	1.018	0.000	1	0.003	0.960	61.4

Test value: alpha=0.05

As can be seen, the logistic regression model was statistically significant, (χ^2 = 0.003 and p = 0.960 > 0.05). The model explains 0% (Nagelkerke R^2 = 0.000) of the amount of the variance in owning an AV and correctly classified 61.4% of cases. The p-value of the predictor "using private cars" Sig = 0.960 > 0.05, so the null hypothesis that the independent variable does not significantly predict the dependent variable is accepted.

Consequently, the results from the cross-tabulation analysis and the logistic regression demonstrate that there is no significant positive relationship between using private cars between the cities or long distances and possibility to own an AV in the future.

5.11.2. Hypothesis 2

Hypothesis 2 involved testing two main sub-hypotheses which explored whether the type of car currently owned or used is a factor in determining how concerned people are about the disappearance of sports vehicles and driving enjoyment after the full adoption of AVs. The structure of this hypothesis is shown in Table 5-29.

Table 5-29. Hypothesis 2 and sub-hypotheses (Author, 2021)

Hypothesis 2	**Questions 3 & 11**
Type of car(s) owned has a significant impact on level of concern about the disappearance of sports cars	**a.** Participants who own or use these type of cars (hatchback, saloon, MPVs) will not be concerned about the disappearance of sports vehicles. **b.** Participants who own or use SUVs, crossovers, coupes or convertibles will be very concerned about the demise of sports vehicles.

Cross-tabulation between the type of owned/used car and concern about the disappearance of the sports vehicle is illustrated in Table 5-30. In addition, linear regression was conducted with the following assumptions:

- Both variables are continuous or categorical.
- There are no significant outliers in the data series.
- The errors are independent (there is no positive relationship between the residual variable and the independent variable).
- The dependent variable has the same variance for all the values of the independent variable (there is homoscedasticity).
- The residual variable is normally distributed.

Table 5-30. Cross-tabulation between the type of car used/owned and concern about the disappearance of sports vehicles (Author, 2021).

Concern about the demise of Sports Vehicles	**What is the type of car you are using, or you prefer to use?**								**Totals**
	Hatchback	Saloon	MPV	SUV	Crossover	Coupe	Convertible	Other	
Extremely concerned	5.00%	5.00%	2.14%	4.29%	1.43%	2.86%	0.71%	0.00%	21.43%
Moderately concerned	8.57%	2.14%	1.43%	2.86%	1.43%	0.71%	0.71%	0.71%	18.57%
Slightly concerned	5.71%	6.43%	1.43%	0.71%	0.00%	0.71%	0.00%	0.71%	15.71%
Neutral	10.71%	5.71%	2.86%	2.14%	1.43%	0.71%	0.71%	0.71%	25.00%
Not at all concerned	8.57%	1.43%	0.71%	0.71%	1.43%	0.00%	0.71%	3.57%	17.86%

Totals	39.29%	20.71%	8.57%	10.71%	6.43%	5.00%	2.86%	5.71%	100.00%
% of people using mode overall	49.07%	65.52%	58.34%	73.38%	44.44%	85.6%	49.65%	24.86%	

a. *Participants who own or use these type of cars (hatchback, saloon, MPV) will not be concerned about the disappearance of sports vehicles.*

The study of this hypothesis involved analysis of the prediction significance level between the use of hatchbacks, saloon and MPVs and the level of concern expressed about the disappearance of sports vehicles, and, in this case, participants who were "not at all concerned". It was expected that people who drive non-sports vehicle would not be concerned about the demise of sports cars and the enjoyment of driving. Thus, hypothesis "a" was presented as follow:

H0: There will be no significant prediction between the independent variable "Participant will not be concerned" and the dependent variable "type of car: Hatchback, Saloon and Multi-purpose vehicles".

H1: There will be a significant prediction between the independent variable "Participant will not be concerned" and the dependent variable "type of car: Hatchback, Saloon and Multi-purpose vehicles".

Simple linear regression was calculated, and the results are shown in Table 5-31. The results show that the regression model found is not significant: (F (1;130) = 1.182, p = 0.279 > 0.05), with an R2 of 0.009, so the null hypothesis is accepted, and the independent variable does not significantly predict the dependent variable.

Table 5-31. Linear regression results; Hypothesis 2a (Author, 2021)

Model	B	Sig.	Beta	R Square	df	F	Sig.

Type 1	0.161	0.279	0.095	0.009	(1;130)	1.182	0.279

Test value: alpha=0.05

Hence, there is no significant positive relationship between participants who own/use these types of cars (hatchback, saloon, MPV) and non-concern about the disappearance of sports cars and the enjoyment of driving. That is to say that the fact that participants drive or use non-sports vehicles does not mean that they will not be concerned about the demise of sports vehicles. On the other hand, the cross-tabulation results (Table 5-30) demonstrate that people who use/own hatchbacks, saloons, or MPVs are concerned about the disappearance of sports vehicles and the enjoyment of driving, with 49.07%, 65.52% and 58.34%, respectively.

b. *Participants who own or use SUVs, crossovers, coupes or convertibles will be very concerned about the disappearance of sports vehicles.*

As with hypothesis 2a, simple linear regression was calculated, and the output of the model was not significant. Therefore, there was no significant positive relationship between participants who own or use SUVs, crossovers, coupes or convertibles and level of concern about the disappearance of sports vehicles and driving enjoyment. This is in contrast to the cross-tabulation analysis results (Table 5-30) which showed that 73.38% of SUV users and 85.6% of coupe users were concerned about the disappearance of sports vehicles and driving enjoyment compared to 44.44% of crossover owners/users and 49.65% of participants who use/own a convertible.

5.11.3. Hypothesis 3

There is debate in the literature about the need to reduce car ownership in order to achieve all the benefits of AVs. Indeed, Grush & Niles (2018a) argue that it is critical to focus on encouraging users to shift to 'ride-buyers' rather than promoting AVs, and Alves (2017) proposed that only the smart use of AVs will result in sustainable mobility. Hence, analysing the reasons behind people's choice to own or share AVs in the future can assist in the promotion of on-demand 'ride-buying' services.

One of these reasons behind this choice is people's familiarity with AVs technologies and their benefits. Therefore, this hypothesis examines the relationship between the extent to which people are familiar with self-driving cars and their future expectations of AV use/ownership. Are people who have heard of AV technologies and know something of AVs potential benefits more likely to want to share than own? And, are people who have not heard of AVs or their benefits more likely to prefer owning instead of sharing? In short, will people's awareness of AVs and their benefits play a role in promoting mobility-on-demand. The structure of this hypothesis is shown in Table 5-32.

Table 5-32. Hypothesis 3 and sub-hypotheses (Author, 2021)

Hypothesis 3	**Questions 4 & 5**
Familiarity with AVs and opinion about them	**a. Participants who have heard of AVs are more likely to own an AV in the future**
	b. Participants who have not heard or not sure of AVs are more likely to share an AV in the future.

Table 5-33 displays the cross-tabulation results between prior knowledge about AVs and expected future use (whether to share or own them). The results show 81.41% of the total participants who wanted to *own* an AV had heard of them before participating in the survey. Meanwhile, 71.45% of the overall participants who wanted to *share* AVs had heard of them before. However, participants who had not heard about AVs before were slightly more likely to opt for sharing rather than owning, at 10.7% and 7.41%, respectively.

Table 5-33.Cross-tabulation between people's familiarity with AVs and owning or sharing one in future (Author, 2021).

Would you like to own or share an AV?	**Have you ever heard of autonomous, driverless or automated cars before?**			**Totals**
	Yes	No	Not Sure	
Own	31.43%	2.86%	4.29%	38.57%

Share		14.29%	2.14%	2.86%	20.00%
Neither		31.43%	4.29%	2.86%	38.57%
Other		1.43%	0.71%	0.00%	2.14%
Totals		78.57%	10.71%	10.00%	100.00%
Overall percentage	*Own*	81.41%	7.41%	11.12%	
	Share	71.45%	10.7%	14.3%	

c. *Participants who have heard of AVs and their benefits are expected to want to own one in the future.*

Based on the cross-tabulation analysis (Table 5-33), people who had heard of AVs were more likely to want to own one. Nevertheless, regression analysis was also conducted to study the relationship further. Therefore, Hypothesis 3 “a” was detailed as follows:

> **H0:** There will be no significant prediction of the dependent variable: "position of participants who have preferred to own an AV" by the independent variable "familiarity with AVs."
>
> **H1:** There will be a significant prediction of the dependent variable: "position of participants who have preferred to own an AV" by the independent variable: "familiarity with AVs."

The results are shown in Table 5-34.

Table 5-34. Logistic regression result: Hypothesis 3a (Author, 2021)

Model	B	Sig.	Beta	R Square	df	F	Sig.
Heard (desire=own)	0.097	0.738	0.047	0.002	(1;52)	0.113	0.738

Test value: alpha=0.05

As the table shows, the found regression model is not statistically significant ($F(1;52) = 0.113$, $p = 0.738 > 0.05$), with an R^2 of 0.002. Therefore, the null hypothesis has been accepted. This is to say that the independent variable does not significantly predict the dependent variable. As a result, there is no significant positive relationship between the position of participants who stated a preference for owning an AV and their prior awareness of driverless vehicles.

Since there is a lack of relationship between familiarity with AV technologies and preference for *owning* them, Hypothesis 3 "b" explores whether a positive significance exists between familiarity with AVs and preference for *sharing* them.

d. *Participants who have heard of AVs and their benefits are expected to want to share them in the future.*

The results from the cross-tabulation (See Table 5-33) indicate that 71.45% of the participants who would prefer to share AVs have heard of them, as opposed to 81.41% of respondents who would prefer to own an AV. Linear regression was then carried out to examine the relationship between preferring to share and having heard of AVs. Thus, Hypothesis 3 "b" was presented as follow:

H0: There will be no significant prediction of the dependent variable: "position of participants who have preferred to share an AV" by the independent variable: "familiarity with AVs".

H1: There will be a significant prediction of the dependent variable: "position of participants who have preferred to share an AV" by the independent variable: "familiarity with AVs".

The results are shown in Table 5-35.

Table 5-35. Logistic regression results: Hypothesis 3b (Author, 2021)

Model	B	Sig.	Beta	R Square	df	F	Sig.
Heard (desire=shared)	0.584	0.031	0.417	0.174	(1;25)	5.257	0.031

Test value: alpha=0.05

As shown in Table 5-35, the found regression model is statistically significant: ($F(1 ;25) = 5.257$, $p = 0.0.031 < 0.05$), with an R2 of 0.174. This means that the model explained 17.4% of the variance in the position of participants about sharing AVs. As a result, the null hypothesis is rejected, and the alternative one is accepted. In other words, the independent variable significantly predicts the dependent variable: for every one-level increase in hearing about AVs (Familiarity), a 0.584-level increase in the position of participants preferring to share AVs is expected.

Consequently, it is expected that people who are acquainted with AVs will share them when they are fully adopted. However, further cross-tabulation between the familiarity of AVs and the suggested list of expected AV benefits was conducted to analyse whether the participants who had heard of AVs selected "Ideas for sharing" as one of the most attractive benefits (See Section 5.6 for a complete analysis of the anticipated benefits). The results are shown in Table 5-36.

Table 5-36. Cross-tabulation between familiarity with AVs and reasons for use (benefits) (Author, 2021)

You would like to use an Autonomous car because of...?	**Have you ever heard of autonomous / driverless or automated cars before?**			**Totals**
	Yes	No	Not Sure	
Safety and reduced crashes	12.17%	1.74%	2.32%	16.23%
New service	7.25%	0.58%	1.16%	9.28%
Reduced driver stress	16.23%	1.45%	0.87%	18.55%
Effectiveness	6.96%	0.29%	0.00%	7.25%
Sustainability	7.54%	0.87%	1.16%	9.57%
Ideas for sharing	2.90%	0.00%	0.00%	2.90%
Reduced congestion	6.09%	1.16%	0.00%	7.25%
Efficient Parking	8.70%	0.29%	2.32%	11.30%
Independent mobility	6.96%	0.58%	1.45%	8.99%
Great opportunities for deliveries	2.90%	0.29%	0.29%	3.48%
Other	3.48%	0.29%	0.00%	3.77%
Totals	82.61%	7.54%	9.57%	100.00%

As the table shows, "Safety and reduced crashes" and "reduced driver stress" were the most attractive benefits for participants who had heard of AVs before and those who had not.

"Ideas for sharing" did not score well among either group, scoring 0.00% among respondents who had not heard of AVs before and just 2.90% among those who had. To conclude, based on the analysis above, it is expected that car ownership will not be reduced when Avs are fully adopted. Of the current sample, only 17.4% of respondents who had heard of AVs were willing to share them. So, the question arises: why are people not prepared to share AVs?

5.11.4. Hypothesis 4

Hypothesis 4 tests whether participants who have heard of AVs before, have expressed a positive opinion about them, and who want to own an AV (independent variables) are more likely to share their data (dependent variable). The reason behind examining this hypothesis is an exploration of how the above factors (independent variables) can play a role in determining what makes participants willing to allow their data to be collected. This will help define the legislative areas to be addressed, taking into account the desires and needs of future users. The structure of the hypothesis is presented in Table 5-37.

Table 5-37.Hypothesis 4 and sub-hypotheses (Author, 2021).

Hypothesis 4	**Questions 5, 6 & 8**
Familiarity with AVs, attitude towards them, and desire to own/share one affects willingness to share data	**a**. Participants who have heard of AVs, feel positive about them, and want to own an AV are likely to want to share their data. **b**. Participants who have not heard of AVs, feel more negative, and neither want to own nor share one (neither) are unlikely to want to share their data.

In this case, multiple regression analysis was used to test Hypothesis 4, which was presented as follows:

> **H0:** There will be no significant prediction of the dependent variable: "participants agree to share their data" by the independent variables: their prior knowledge of AVs, their desire to own or share an AV, and their opinion about them (positive or negative).

H1: There will be a significant prediction of the dependent variable: "participants agree to share their data" by the independent variables: their prior knowledge of AVs, their desire to own or share an AV and their opinion about them (positive or negative).

The results are shown in Table 5-38.

Table 5-38. Multiple regression results: Hypothesis 4 (Author, 2021)

Model	B	Sig.	Beta	R Square	df	F	Sig.
own/share	0.164	0.397	0.081	0.052	(3;135)	2.480	0.064
position	0.400	0.064	0.178				
heard	0.321	0.074	0.163				

Test value: alpha=0.05

The results in Table 5-38 demonstrate that the overall regression model is not significant (F(3;135) = 2.480, p = 0.064 > 0.05), with an R2 of 0.052. This is not significant when taking all three independent variables into account altogether. Thus, in this case, the null hypothesis that the independent variables do not significantly predict the dependent variable is accepted, and it cannot be explained in level 0.05. The p-value of the predictor For the variable "Would you like to own AV?"; as shown the Sig = 0.397, so this independent variable does not predict the dependent variable.

However, analysing the results in Table 5-38, two independent variables are found to predict the dependent variable:

- Firstly, for the variable "Opinion about AVs: Positive", Sig = 0.064. Hence, this independent variable predicts the dependent variable. Accordingly, for every one-level increase in the positivity of participants' opinions about AVs, the possibility of sharing their data is expected to increase by a 0.178.
- Secondly, concerning the variable "Familiarity; heard/have not heard of AVs""; the Sig level is 0.074. Likewise, this independent variable predicts the dependent

variable, and for every one-level increase in the familiarity with AVs, a 0.163-level rise in the possibility of sharing their data is expected.

Consequently, there is no significant positive relationship between the desire of participants to own or share an AV and their acceptance of sharing their data. However, there is a meaningful positive relationship between both the attitude of participants towards AVs (positive or negative), their acquaintance with them, and their willingness to share their data at the level 0.1. To conclude, participants who have heard of AVs and feel more positive towards them are likely to share their data, and participants who have not heard of AVs and feel more negative are unlikely to be willing to share their data.

5.11.5. Hypothesis 5

This hypothesis examines the relationship between the parties respondents blame in case of accidents (Manufacturers, City Planners, Owner, Insurance company) and the factors studied in the previous hypotheses, such as the desire to own/share an AV or the use of private cars *v*. public transport. Four sub-hypotheses were developed: the first three focus on participants who are currently using/owning private cars, whereas, the fourth focuses on participants who currently use public transport. The structure of this hypothesis is shown in Table 5-39.

Table 5-39. Hypothesis 5 and sub-hypotheses (Author, 2021)

Hypothesis 5	**Questions 1 & 2 and Questions 6 & 10**
AV type of ownership and type of transport mode affect the view of the party held liable in case of an accident	**a**. Participants who currently use/own private cars and want to own AVs blame manufacturers. **b**. Participants who currently use private cars and want to own AVs blame insurance companies. **c**. Participants who currently use private cars and want to own AVs blame all the above. **d**. Participants who currently use public transport (e.g. Taxi, Bus, Tram, Train, Carpooling) and want to share AVs blame city planners and AV owners.

e. *Participants who currently use/own private car and want to own an AV in the future are blaming Vehicle manufacturers.*

This presumes that participants are blaming manufacturers because they are currently using private cars and wish to own AVs in future. Hypothesis 5 "a" can be reformulated as follows:

H0: There will be no significant prediction of the dependent variable: "participants are blaming manufacturers" by the independent variables: "their desire to own an AV" and "their use/own of private cars".

H1: There will be a significant prediction of the dependent variable: "participants are blaming manufacturers" by the independent variables: "their desire to own an AV" and "their use/own of private cars".

Multiple regression was again employed, and the results are given in Table 5-40.

Table 5-40. Multiple regression results: Hypothesis 5a (Author, 2021)

Model	B	Sig.	Beta	R Square	df	F	Sig.
own	0.115	0.200	0.112	0.016	(2;133)	1.064	0.348
private	0.046	0.389	0.075				

Test value: alpha=0.05

The results demonstrate that the found regression calculation is not significant ($F(2;133) = 1.064$, $p = 0.348 > 0.05$), with an R2 of 0.016. As a result, the null hypothesis is accepted, and the alternative is rejected. In the level 0.05, the independent variables do not significantly predict the dependent variable. Consequently, there is an absence of a significant positive relationship between participants who currently use/own private cars and who are interested in owning AVs in the future and their blaming of manufacturers in the case of an accident.

f. *Participants who currently use/own private car and want to own an AV in the future are blaming insurance companies.*

The second assumption is similar to the first in terms of the independent variables: "Participants who are "currently using/own private car" and "willing to own an AV in the future". However, this hypothesis investigates whether insurance companies can also be held liable. Multiple regression is applied, and hypothesis 5 "b" is rewritten as follows:

> **H0:** There will be no significant prediction of the dependent variable: "participants are blaming insurance companies" by the independent variables: "their desire to own an AV" and "their use/ownership of private cars".
>
> **H1:** There will be a significant prediction of the dependent variable: "participants are blaming insurance companies" by the independent variables: "their desire to own an AV" and "their use/ownership of private cars".

The results are shown in Table 5-41.

Table 5-41. Multiple regression results: Hypothesis 5b (Author, 2021)

Model	B	Sig.	Beta	R Square	df	F	Sig.
own	0.022	0.145	0.127	0.026	(2;133)	1.780	0.173
private	0.013	0.168	0.120				

Test value: alpha=0.05

Table 5-41 demonstrates that the found regression equation is not significant (F(2;133) = 1.780, p = 0.173 > 0.05), with an R2 of 0.026, so the null hypothesis that the independent variables do not significantly predict the dependent variable is accepted, and it cannot be explained in level 0.05. Correspondingly, a significant positive relationship is not present between participants who are currently using/owning private car and willingness to own an AV in the future and the blame of insurance companies.

g. *Participants who currently use/own private cars and want to own an AV in the future are blaming all the above (Manufacturers, City Planners, Owner, Insurance company).*

Sub-hypotheses 5 "a" and "b" have shown that there is no significance in the relationship between using private cars and the desire to own an AV in the future and whether the participants blame manufactures or insurance companies. Sub-hypothesis "c" examines the relationship between the same independent variables and the dependent variable: "all the above" (Manufacturers, City Planners, Owner, Insurance company). This to analyse if the parties should share the responsibility. Hence, hypothesis 5 "c" was presented as follows:

H0: There will be no significant prediction of the dependent variable: "participants are blaming all the above (Manufacturers, City Planners, Owner, Insurance company)" by the independent variables: "their desire to own an AV" and "their use/ownership of private cars".

> **H1:** There will be a significant prediction of the dependent variable: "participants are blaming all the above (Manufacturers, City Planners, Owner, Insurance company)." by the independent variables: "their desire to own an AV" and "their use/ownership of private cars".

The results are shown in Table 5-42

Table 5-42. Multiple regression results: Hypothesis 5b (Author, 2021)

Model	B	Sig.	Beta	R Square	df	F	Sig.
own	0.007	0.929	0.008	0.001	(2;133)	0.039	0.962
private	0.011	0.804	0.022				

Test value: alpha=0.05

As per Table 5-42, the found regression equation is not significant (F(2 ;133) = 0.039, p = 0.962 > 0.05), with an R2 of 0.001. At level 0.05, the independent variables do not significantly predict the dependent variable, and cannot explain it. The null hypothesis is accepted, and the alternative is rejected. Therefore, participants who are currently using/owning private cars and want to own an AV in the future are not blaming "all the above" (Manufacturers, City Planners, Owner, Insurance company).

h. *Participants who use public transport (e.g. Taxi, Bus, Tram, Train, Carpooling) and want to share AVs in the future are blaming city planners and owners.*

While sub-hypotheses "a", "b" and "c" studied car ownership and its impact on determining the responsible party in the event of an accident, sub-hypothesis "d" assesses whether participants who use public transport now and who intend to share AVs in the future will blame city planners and AV owners in the case of an accident. Hypothesis 5 “d” was presented as follows:

H0: There will be no significant prediction of the dependent variable: "participants are blaming city planners and Owner" by the independent variables: "their use of public transport" and "their desire to share AV".

H1: There will be a significant prediction of the dependent variable: "participants are blaming city planners and Owner" by the independent variables: "their use of public transport" and "their desire to share AV".

Table 5-43. Multiple regression results: Hypothesis 5d (Author, 2021).

Model	B	Sig.	Beta	R Square	df	F	Sig.
Share	0.150	0.035	0.182	0.145	(2;133)	3.157	0.046
Public	0.037	0.123	0.132				

Test value: alpha=0.05

Results from Table 5-43 shows that the overall regression model is significant (F (2;133) = 3.157, p = 0.046 < 0.05), with an R2 of 0.145. Hence, this means that the model explained 14.5% of the variance in the blaming of city planners and owners. As a result, the null hypothesis is rejected, and the alternative is accepted, and the independent variables significantly predict the dependent variable. However, not all the independent variables are significant in terms of predicting the dependent variable. The following section explains each variable separately and its significance level.

- The independent variable "share" is significant (Sig = 0.035), which can predict and explain the dependent variable "blaming city planners and owners", and for every one-level increase in the desire of sharing an AV, a 0.182-level increase in the blaming of city planners and owners is expected.
- The independent variable "public" is not significant (Sig = 0.123), so, it can neither predict nor explain the dependent variable "blaming city planners and owners".

To sum up, in the event of an accident, participants who are willing to share AVs are more likely to blame city planners and owners. However, there is no positive relationship between respondents who use public transport and their blaming of city planners and owners.

5.11.6. Hypothesis 6

This hypothesis examines if the current model of vehicle owned/used by participants can impact the future use of AVs in terms of sharing or owning them. In the survey, participants were asked about the kind of car they use or own and their opinion about their future use of AVs (owning or sharing). However, this hypothesis focuses on the variable "own an AV". The structure of the hypothesis is shown in Table 5-44.

Table 5-44. Hypothesis 6 (Author, 2021)

Hypothesis 6	**Questions 4 & 5**
Type of vehicle owned/used currently predict the future use of AVs (Own/share)	**a.** Participants who own hatchbacks, saloons, and/or multi-purpose vehicles (MPVs) would desire to own AVs in the future

Multiple regression is used and the hypothesis is presented as follows:

H0: There will be no significant prediction of the dependent variable: "own an AV" by the independent variable: "type of vehicle used/owned".

H1: There will be a significant prediction of the dependent variable: "own an AV" by the independent variable: "type of vehicle used/owned".

Table 5-45 below demonstrates the outcomes of the conducted multiple regression for Hypothesis 6.

Table 5-45. Multiple regression results: Hypothesis 6 (Author, 2021)

	Overall	***Hatchback***	***Saloon***	***MPV***	***SUV***	***Crossover***	***Coupe***	***Convertible***	***Other***
R^2	*0.105*	*0.127*	*0.112*	*0.255*	*0.045*	*0.122*	*0.018*	*0.017*	*0.020*
Df1	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
Df2	*136*	*54*	*27*	*9*	*12*	*7*	*5*	*2*	*6*
F	*16.002*	*7.870*	*3.396*	*3.083*	*0.568*	*0.977*	*0.091*	*0.035*	*0.125*
F-Sig	*0.000*	*0.007*	*0.076*	*0.113*	*0.466*	*0.356*	*0.775*	*0.868*	*0.736*
B	*0.175*	*0.207*	*0.200*	*0.340*	*0.101*	*0.144*	*0.093*	*0.038*	*0.286*
β	*0.325*	*0.357*	*0.334*	*0.505*	*0.213*	*0.350*	*0.133*	*0.132*	*0.143*
B-Sig	*0.000*	*0.007*	*0.076*	*0.113*	*0.466*	*0.356*	*0.775*	*0.868*	*0.736*

Test value: alpha=0.05

The results indicate the following points:

- The overall found regression model is significant ($F (1;136) = 16.002$, $p = 0.000 < 0.05$), with an R2 of 0.105. In addition, a significant positive value of the predictor's coefficient ($B = 0.175$ with $p = 0.000$) was found. Thus, at level 0.05, we can say that the current vehicle model owned/used by participants is likely to affect the choice to own an AV. This means that for every one-level increase in the type of car owned/used, a 0.325-level increase in the desire to own an AV ($\beta = 0.325$) is expected.

- In the case of participants who use/own hatchbacks, the found regression model is significant ($F(1;54) = 7.870$, $p = 0.007 < 0.05$), with an R2 of 0.127 with a positive significant value of the predictor's coefficient ($B = 0.207$ with $p = 0.007$). Hence, participants who use/own the type of car "hatchback" are likely to own an AV in the future. This means that for every one-level increase in owning/using a hatchback, a 0.357-level increase in the desire to own an AV ($\beta = 0.357$) is expected.

- On the other hand, for participants who use/own saloons, the found regression model is not significant at level 0.05. However, it is significant at the level 0.1 ($F(1;27) = 3.396$, $p = 0.076 < 0.1$), with an R2 of 0.045, with a positive significant value of the predictor's coefficient ($B = 0.200$ with $p = 0.076$). As a result, similar to hatchback owners/users, participants who use/own saloons are likely to own an AV in the level 0.1. This means that for every one-level increase in owning/using a Saloon type of car, a 0.334-level increase in the desire to own an AV ($\beta = 0.334$) is anticipated.

- The remaining models (MPV, SUV, Crossover, Coupe and Convertible) did not demonstrate any significance, and thus, it is not possible to assume that there is no relationship. A more significant sample is needed to focus on these types of cars and study whether the current model is critical in determining the direction of future use of AVs in terms of owning or sharing them.

5.12.Conclusion

It is vital to understand public opinion relating to AVs to facilitate the adoption of AV technologies and encourage a shift towards shareability. The primary purpose of this chapter, therefore, was to study users' behaviour regarding their acceptance of and reaction to AVs. This chapter addressed Objective 4 in detail and provided answers to the question: "How will users' behaviour change?"; it also analysed different aspects of users' behaviour, drawing on a range of statistical tests, including multiple regression analysis. It identified the current modes respondents use to move in the city and between cities, their familiarity with AVs, their willingness to own or share an AV in the future, and their expectations of the benefits of AVs, including how they would spend time while travelling in an AV. It went on to explore areas of potential uncertainty or concern, namely, participants' willingness to share personal data, their levels of concern about the potential disappearance of sports vehicles and the enjoyment of driving, their opinions regarding the party responsible in the event of an accident, and their views of the barriers to AV adoption in general. Furthermore, this chapter also provided analysis of six main hypotheses that tested the relationships between key variables and users' expectations about owning or sharing an AV, their concerns about the potential disappearance of sports vehicles, their willingness to share their data, and the parties they would blame in the event of an accident, in order to identify their influence on AV usage in the future.

As a result, the findings of this part of the study have found that AVs ownership is expected to increase compared to what was found in the literature review that AVs will reduce ownership (Santi et al., 2014). On the other hand, the findings of this study found that familiarity with AVs creates a positive link for end-users to adopt them which aligns with what (Panagiotopoulos & Dimitrakopoulos, 2018) believe that AVs have to be commercialised and portrayed positively.

Chapter 6: Final Framework, Recommendations and Conclusions

Content

Chapter 6: Development of the Final Framework, Recommendations and Conclusions

6.1. Introduction

This research study aimed to explore the potential of autonomous vehicles and develop an adaptive urban framework to assist planners, citizens, politicians, and stakeholders in their planning decision-making regarding AVs. The novelty of this research lies in the development of this framework, which addresses the barriers to full AVs adoption from technical, urban, social and legislative perspectives, and in the recommendations which arise from the study and the proposed framework. This chapter begins by explaining how the final framework was developed, then presents the framework itself and goes on to proposes a series of recommendations for urban planning to support AV adoption. It then provides answers to each of the research questions and explains the contribution to knowledge the study makes. The chapter concludes by setting out the limitations of the current research and suggesting avenues for further study which might overcome them.

6.2. Development of the Final Framework

The study was designed to investigate the potential of AV technologies and their impact on cities, mainly urban planning, and develop a framework that will help in the adoption of AVs. Initial analysis of recent literature indicated that the existing research focused largely on the maturity of the technology and the development of the different sensors required to enable AVs to function effectively. Therefore the gap identified was to look into AVs impact on urban planning and how end-users' behaviour and attitudes towards AVs might affect the shift from ownership to shared mobility, which in turn will affect urban planning.

The study started with an extensive analysis of the existing literature to identify the current barriers to full AV adoption (Level 5 - Full automation) (See Table 1-1). A systematic review utilising NVIVO Pro 12 was used to identify the technical, social and legislative obstacles slowing or preventing AV adoption, and this led to the development of a conceptual framework of current AVs barriers, the factors which affect them, and their interrelations (See Chapter 2 Figure 2-12). The literature review also examined AV vehicle specifications to create an overview of the AV system architecture and identify its components. This was achieved through document analysis of articles which explored the technologies required for complete automation, as well as case studies that tested AVs on the roads. This analysis led to the creation of a detailed plan of the AV system architecture, highlighting three main areas: Input, Processing and Output. The final output of the literature review phase involved combining the system architecture overview with the AV barriers framework to identify whether the barriers impacted individual areas (input, processing and/or output) or the system architecture as a whole (See Chapter 2 Figure 2-1).

The next step was to validate the contents of the combined framework through expert evaluation. This was facilitated through a questionnaire developed for experts in a range of disciplines related to AVs, including urban planning, IT, transportation, traffic simulation, traffic accidents, environmental management, wireless communication, and machine learning. An adapted version of the framework was presented to the experts and they were asked to evaluate its contents and identify any omissions; thus, the primary purpose of the survey questionnaire was not only to validate the framework but also to identify further barriers based on experts' opinions. As part of the process, the experts were asked to rate the barriers identified based on their importance, and they were prioritised as follow:

1. Safety
2. Data processing (Computer software and hardware)
3. Accurate positioning and mapping
4. V2X communication
5. Users acceptance and behaviour

6. Ethics
7. Affordable sensors

In addition, the experts were asked to consider a hypothetical journey through the centre of Nottingham to assess the impacts of AVs on urban planning with a focus on design principles, detailed design issues, and design guidance based on MFS 1 (See Chapter 4). The combined framework was also the primary source for generating a survey questionnaire for members of the public in Nottingham to evaluate potential users' reactions to and acceptance of AVs. Thus, the development of both surveys was influenced by the combined framework, and they in turn influenced the development of the final urban planning framework and the recommendations to support the adoption of AVs set out below.

6.3. The Final Urban Planning Framework

The outcomes of each phase of the study (Phases I, II and III) informed the development of the final framework which includes the recommendations which arose from the literature review (See Chapter 2 Figure 2-12) and the study recommendations which are set out in Table 6-1. The table itself is presented in Figure 6-1 and demonstrates the interrelatedness of the established barriers and sub-barriers, the factors that contribute to them, their impact on the AV system architecture, and the recommendations to address them.

6.4. Recommendations Arising from the Study

The outcomes of all the research phases informed the development of a series of recommendations to support the successful adoption of AVs, focusing primarily on the urban changes required. Table 6-1 presents these recommendations, showing how these recommendations have been developed based on the barriers, sub-barriers, the factors that contribute to them, and the recommendations arising from the literature review.

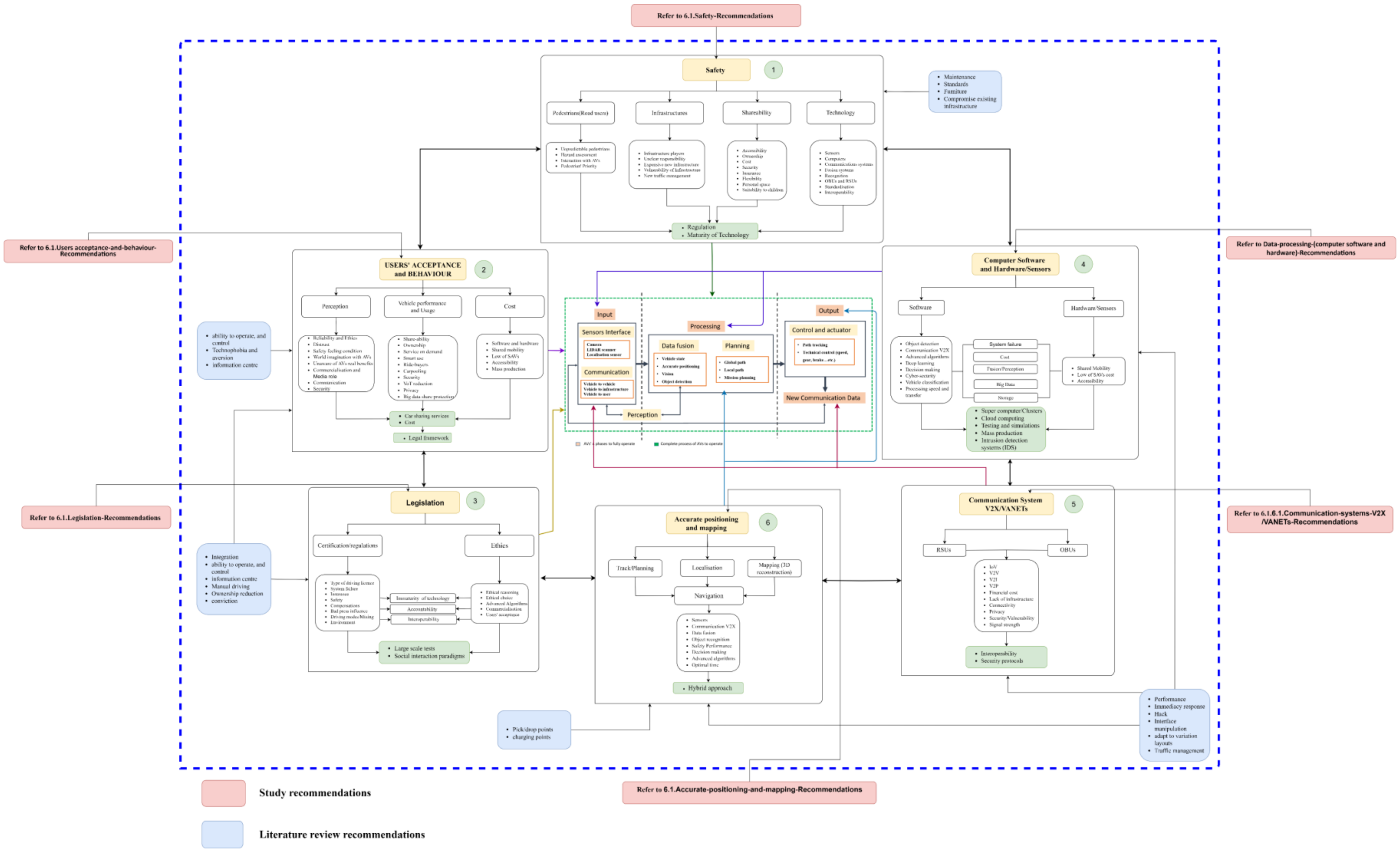


Figure 6-1. The final urban planning framework to support the adoption of autonomous vehicles (Author, 2021).

Table 6-1. Recommendations Arising from the Study (Author, 2021).

Category	Barrier	Sub-barrier	Factors	Summary of previous recommendations (Systematic review)	Recommendations for urban planning and the overall adoption of AVs
User /government perspectives	**Safety**	Pedestrians (Road users)	• Unpredictable pedestrians • Hazard assessment • Interaction with AVs • Pedestrian' Priority	• Regulations • Maturity of technology	**Safety - Recommendations** • To consider V2X communication servers' location • To prioritise pedestrian movements to comply with MFS requirements • To create/develop infrastructure departments/ units that deal with and maintain the urban changes • To upgrade traffic light systems to smart to enable V2X • Consider changes of the new technologies in planning • The direction of ownership and shareability will affect drop-off/pick-up points and many other design principles • To identify clear responsibility between Manufacturers, City Planners, Owners, Insurance companies in case of an accident or malfunction • To create AVs hubs in each neighbourhood.
		Infrastructure	• Infrastructure players • Unclear responsibility • Expensive new infrastructure • Vulnerability of Infrastructure • New traffic management		
		Shareability	• Accessibility • Ownership • Cost • Security • Insurance • Flexibility • Personal space • Suitability to children		
		Technology	• Sensors • Computers • Communications systems • Fusion systems • Recognition • OBUs and RSUs • Standardisation • Interoperability		
	Legislation	Certification / regulations	• Type of driving licence • System failure • Insurance • Safety • Compensations • Bad press influence • Driving modes/Mixing • Environment	• Immaturity of technology • Accountability • Interoperability • Large-scale tests • Social interaction paradigms	**Legislation-Recommendations** • To focus on developing the city planning further to accommodate AVs, which will help to reduce vehicle ownership.

		Ethics	• Ethical reasoning • Ethical choice • Advanced Algorithms • Commercialisation • Users' acceptance		• To consider new road design lanes to accommodate both driving modes (autonomous and manual). • To update the regulations regarding accidents, urban damage, and compensation. • Spaces to accommodate system failure. • To exploit existing parking and create underground/overground hubs parking particularly for AVs. • To ban manual driving in order to decrease vehicle ownership.
	Users' acceptance and behaviour	Perception	• Reliability and Ethics • Distrust • Safety feeling condition • World imagination with AVs • Unaware of AVs real benefits • Commercialisation and Media role • Communication • Security	• Car-sharing services • Cost • Legal framework	**Users' acceptance and behaviour - Recommendations**
		Vehicle performance and usage	• Shareability • Ownership • Service on demand • Smart use • Ride-buyers • Carpooling • Security • VoT reduction • Privacy • Big data share protection		• To study the users' behaviour further as it will dictate the actual impacts of AVs on urban planning. • To promote shifting to mobility-on-demand, public transportation users are likely to use shared AVs. In contrast, users using private cars are likely to own AVs. • To create hubs to facilitate mobility-on-demand in each neighbourhood. • To consider creating leisure developments in case of the disappearance of the sports car and the banned of manual driving. • To raise awareness of AVs benefits to promote SAVs, which in turn will help plan various design issues such as hubs, load/unload points, road restrictions etc. • To develop systems to protect the privacy of users. This can be through various technologies installed in intersections, along the road, or in different parts of the city.
		Cost	• Software and hardware • Shared mobility • Low of SAVs • Accessibility • Mass production		
		RSUs	• IoV • V2V • V2I		**Communication systems V2X /VANETs - Recommendations**

ICT	**Communication systems V2X/VANETs**	 OBUs	• V2P • Financial cost • Lack of infrastructure • Connectivity • Privacy • Security/Vulnerability • Signal strength	• Interoperability • Security protocols	• To investigate the best location of Road-Side Units (RSUs). • To use different protocols to strengthen connectivity and signals in urban areas. • To implement protocols to enable interoperability.
	Accurate positioning and mapping	Track/planning Localisation Mapping (3D reconstruction)	• Sensors • Communication V2X • Data fusion • Object recognition • Safety Performance • Decision-making • Advanced algorithms • Optimal time	• Hybrid approach	**Accurate-positioning-and-mapping-Recommendations** • To implement a hybrid approach to facilitate position and mapping. • To start building comprehensive libraries for object recognition. • To mass-produce sensors to be available and decrease the cost of AVs.
	Data processing (Computer software and hardware)	Software Hardware / Sensors	• Object detection • Communication V2X • Advanced algorithms • Deep learning • Decision-making • Cyber-security • Vehicle classification • Processing speed and transfer	• System failure • Cost • Fusion/Perception • Big Data • Storage • Supercomputer/Clusters • Cloud computing • Testing and simulations • Mass production • Intrusion detection systems (IDS)	**Data processing (computer software and hardware)-Recommendations** • To encourage large-scale tests to advance the required technology. • To enforce new legislation against cybernetics and data protection. • To advance simulation software to study their safety further. • To develop systems such as (IDS) for efficiency and safety.

6.5. Answering the Research Questions

The following section sets out the answers to the research questions and demonstrates how the aim and objectives of this research were achieved. The relation between the aim, objectives and research questions is illustrated in Table 6-2.

Table 6-2. Summary of the research aim, objectives and research questions (Author, 2020).

Research Aim	Objectives	Research questions
To explore the barriers to AV adoption and develop an urban design model to assist planners, citizens, politicians, and stakeholders in their planning decision-making regarding AVs.	1: To identify and analyse the barriers to AV adoption in today's cities.	1: What are the barriers and obstacles preventing the adoption of AVs in today's cities?
	2: To analyse AV vehicle specifications and their impact on the urban transportation infrastructure	2: What are the technologies and infrastructures which need to be evolved to accommodate AVs? Car specifications?
	3: To determine the possible impacts on city planning and urban transport infrastructure	3: Which street design elements and design guidance are most likely to be affected by the integration of AVs into the city's transport infrastructure?
	4: To analyse and measure users' current behaviour in respect of AVs	4: How do potential users' regard AVs now and how can they be encouraged to adopt AVs in the future?
	5: To develop an urban design framework to help transport infrastructure adapt to AVs and propose recommendations	What steps should be taken to help the city's urban structure adapt to AVs?

Research Question 1

6.5.1. What are the barriers and obstacles preventing the adoption of AVs in today's cities?

A systematic review through content analysis of current literature relating to AVs was employed to identify the barriers and obstacles to the adoption of AVs in our cities. 140 sources were analysed using NVIVO 12 Pro to investigate these AVs barriers. Word frequency, text search, and clustering techniques were used to identify the potential AVs barriers. Conceptual analysis and clustering were then adopted, leading to the development of the AVs barriers framework set out in Chapter 2. The barriers identified were categorised into two main groups: issues relating to ICT and those relating to Users or the Government. The former included (i) Computer software and hardware, (ii) Communication systems V2X, and (iii) Accurate positioning and mapping, while the latter included (i) Users' acceptance and behaviour, (ii) Safety, and (iii) Legislation.

Research Question 2

6.5.2. What are the technologies and infrastructures which need to be evolved to accommodate AVs? Car specifications?

Document analysis was used to identify AV's technical specifications and map the overall system architecture. NVIVO 12 Pro was used as a tool to analyse the sources. The outcome of the analysis revealed that several technologies and sensors are required to enable complete and safe autonomous operation. These are deployed in three separate phases: Input, Processing and Output (See Figure 2-1). The input phase is where most sensors are required, notably cameras, LiDAR scanners, and localisation sensors. These sensors are critical to gathering the data which is then analysed in the Processing phase. Perception, data fusion, and planning are the stages needed to identify objects through object detection mechanisms. This can be done via advanced computers and clustering, where all the data are fused to determine the vehicle's state, accurate positioning, and vision.

Research Question 3

6.5.3. Which street design elements and design guidance are most likely to be affected by the integration of AVs into the city's transport infrastructure?

A mixed methodology was employed to answer this question utilising a review of the literature and a semi-structured survey questionnaire designed for experts in a range of disciplines related to AVs. They were asked to analyse a hypothetical journey through the city of Nottingham and identify the likely impacts on street design if the trip was made by a fully autonomous vehicle. A number of aspects likely to be affected were identified through the literature review, notably from the Manual For Street 1, and the experts were asked to consider the following areas in particular: a) design elements that would be affected, b) elements that would be removed, c) AVs' overall impacts on MFS guidelines for design, d) AVs and car ownership e) AVs and parking/storage, and f) the phasing of overall AV implementation, including whether manual cars should be banned.

According to the experts, roundabout/intersections, zebra crossings, charging points, on-street parking, road signs and drop points will be more severely affected than other design elements. Similarly, design guidance will be affected, particularly layout and connectivity, parking and traffic signs and marking. Furthermore, the experts strongly believe that the issue of storage for AVs is essential and existing parking in the city and creating new dedicated parking hubs should be considered, possibly in each neighbourhood. Regarding the implementation of AVs, the experts suggested starting with motorways (connecting cities); however, they were not in favour of banning manual driving as this was thought likely to influence ownership growth and thus affect urban planning.

Research Question 4

6.5.4. How do potential users' regard AVs now, and how can they be encouraged to adopt AVs in the future?

This question was addressed through a quantitative methodology using a structured survey questionnaire to explore end-user behaviour in regard to AVs acceptance and reaction. Six hypotheses were tested using different statistical models, such as multiple regression tests. Therefore, the behaviour was studied from different perspectives. The survey outcomes suggested that users' behaviour will change. Firstly, hypothesis one analysed the relationship between the current mode of transportation used and future expectations of AVs use in two different contexts in the city and between cities. In addition, the hypothesis analysed the relationship between the mode of transport used and the participants' desire to share or own an AV in the future. The second hypothesis investigated the relationship between the type of vehicle used and respondents' concerns about the disappearance of sports vehicles and the enjoyment of manual driving. Hypothesis three explored the relationship between to what extent people are familiar with self-driving cars and their future expectations of use. The fourth hypothesis studied the link between familiarity with AVs and the willingness of users to share their data. Hypothesis five examined the association between own/share an AV, use/ownership of private cars and the party to be held responsible in the event of an accident. Finally, hypothesis six looked at the type of vehicle owned/used and the expectation of owning/sharing an AV in the future.

Research Question 5

6.5.5. What steps should be taken to help the city's urban structure adapt to AVs?

The answers to this question were identified using a qualitative method by combining the outcomes of Phases I, II and III of this study to create the final urban planning framework (See Section 6.3) and propose a set of recommendations to support the successful adoption of AVs in urban environments. Together, these identify the barriers and sub-barriers to AV adoption, their associated factors, their impacts on the AV system architecture, and set out the steps which should be taken to address them. These cover the technological, social and regulatory arenas, and make specific recommendations addressing safety, legislation, user acceptance and behaviour, AV communication systems, accurate positioning and mapping, and data processing (computer software and hardware).

6.6. Contribution to Knowledge

This study aimed to develop an urban planning framework to assist planners, citizens, politicians, and stakeholders in their planning decision-making regarding AVs. The originality of this research contribution lies in the quality of the framework it proposes as well as the methodology that has been developed. While previous studies have focused largely on technical matters and discussed issues in isolation, this study has analysed a broad range of possible barriers that hinder the full adoption of AVs in our cities and considered the potential implications of AV adoption at the urban, social and legislative levels.

To the best of the researcher's knowledge, this study is the first to:

- identify the barriers to AV adoption at the urban, social and legislative levels, taking into account various automation levels from low (no automation) to high (full automation) and suggest possible solutions to overcome them; This is believed to be the first step to address before address any urban impacts. Therefore, the framework of the barriers will aid to identify further the urban impacts;
- propose a framework for the integration of AVs into the existing infrastructure which takes account of both user behaviour and AVs' potential impacts on urban street design; This integration will determine the grey areas of what is needed in the future and what can be adjusted from the existing infrastructure. For instance, the communication aspect and the OBUs.
- employ a mixed-methods research methodology to establish the framework of barriers preventing full adoption of AVs and identify possible solutions;
- to study the behaviour of users in a specific city (Nottingham) and the extent to which they accept AVs technologies and usage in order to identify the various incentives and

barriers at play and propose steps to enhance future AV adoption. Familiarity with AVs doesn't mean that Ownership will be reduced.

6.7. Limitations of the Research

All research studies have strengths and weaknesses (Connelly, 2013), and every study has its limitations. The emergence of the COVID-19 pandemic during the course of this research also imposed a number of unanticipated restrictions, and these limited the practical scope of the study. The main limitations associated with this study are listed below:

The identification of barriers to full AVs adoption were limited to some extent as AVs have not yet been introduced anywhere in the world and the topic is still under investigation. However, only literature published between 2012 and 2019 was included in the review to try to utilise the most up-to-date research findings. In addition, there is a lack of previous studies exploring AVs from non-technical perspectives, notably their influence on urban, social, and legislative domains. Additional barriers may emerge as further research is conducted, including those proposed by the experts consulted in this study.

Recruiting an appropriate balance of experts was another difficulty in this study, especially those from the manufacturing sector. Although the aim of Objective 3 was to validate the framework and study the proposed journey from various perspectives, namely city planning (Urban planning), ICT, and Vehicle manufacturers, it proved difficult to recruit vehicle manufacturers. This may be due to concerns that participating in the survey would reveal market sensitive information about their products. In addition, the study identified that insurance companies will play a role in adopting AVs; however, it proved impossible to recruit experts from insurance companies despite surveys being sent to many organisations.

Simulation of Urban MObility (SUMO) software was going to be used to simulate the journey proposed in Phase II to analyse the urban impacts of AVs. However, access to the lab to conduct simulation-based research was severely restricted due to the COVID-19 pandemic. Therefore, due to the limited timeframe for this doctoral study, the simulation was cancelled, and it will be considered for future research.

Although Objective 4 was set to be exploratory to study the end-users behaviour in terms of their reaction and acceptance of AVs, the sample size studied was just 140 participants, making it difficult for the statistical tests to identify significant relationships. Therefore, it was difficult to establish clear links between current attitudes and behaviour and future AV use. Similar research using a larger sample size would have been more accurate and could have been generalised to a broader context. However, it was still possible to make some recommendations to promote AV adoption based on current user attitudes and behaviour.

6.8. Recommendations for future research

In light of the limitations identified above, future research could focus on developing the framework, conducting simulation-based research, considering a more prominent and representative sample, and having an actual test of AV on our roads. These possible directions are outlined in more detail:

6.8.1. Framework development

The framework developed in this study was established through a systematic literature review and survey questionnaires. At this stage, the framework comprises six main barriers. However, it is anticipated that more barrier will emerge over time. This means that more obstacles will need to be investigated, both by analysing the literature review further using meta-synthesis and by including studies published after 2019. Conducting simulations, considering a representative sample, and running tests in urban areas will also help to refine the framework and provide more accurate and reflective content.

6.8.2. Simulation-based research

Simulation-based research methods can provide insights into the subject matter before actual implementation, and significant time and cost have been expended (Müller & Pfahl, 2008). Simulation of the proposed journey in Phase II would provide greater insights into the impacts of AVs on the design principles and design issues and could also assist in examining the effects of AVs on O_2 emissions, time, shareability, intersections, V2X, and route choice, for example.

6.8.3. Sample size and expertise

Analysing a larger sample for the public survey would help for generalisation purposes and generate results which could be tested statistically to greater effect. Another step to consider would be to recruit more experts to study the developed framework, the AV barriers and the impacts of AVs on urban planning, notably from the fields of vehicle manufacturing and insurance. This would help to broaden the knowledge around AVs and address the expected benefits and risks more appropriately.

6.8.4. Practical implementation

Large-scale tests are encouraged and indispensable to understand how AVs will be deployed on our roads (De Bruyne & Werbrouck, 2018). Therefore, a desirable next step would be to arrange an AV test and analyse its performance. Such tests would help to analyse the AV's performance in different traffic scenarios, urban settings, weather conditions, and at day and night time. This could also be an excellent opportunity to portray AVs positively and for the public to see how safe they are.

References

Aarhaug, J., & Olsen, S. (2018). Implications of ride-sourcing and self-driving vehicles on the need for regulation in unscheduled passenger transport. *Research in Transportation Economics*, *69*(June), 573–582. https://doi.org/10.1016/j.retrec.2018.07.026

Abbasi, I., & Shahid Khan, A. (2018). A Review of Vehicle to Vehicle Communication Protocols for VANETs in the Urban Environment. *Future Internet*, *10*(2), 14. https://doi.org/10.3390/fi10020014

Abowitz, D. A., & Toole, T. M. (2010). Mixed Method Research: Fundamental Issues of Design, Validity, and Reliability in Construction Research. *Journal of Construction Engineering and Management*, *136*(1), 108–116. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000026

Ackermann, C., Beggiato, M., Schubert, S., & Krems, J. F. (2019). An experimental study to investigate design and assessment criteria: What is important for communication between pedestrians and automated vehicles? *Applied Ergonomics*, *75*(November 2018), 272–282. https://doi.org/10.1016/j.apergo.2018.11.002

ADS Team. (2019). *Driving Automation Systems: Advanced Driver Assistance Systems (ADAS) and Automated Driving Systems (ADS) | SFMTA*. https://www.sfmta.com/projects/driving-automation-systems-advanced-driver-assistance-systems-adas-and-automated-driving

Agarwal, O. P., Kumar, A., & Zimmerman, S. (2019). Vehicles. In O. P. Agarwal, A. Kumar, & S. B. T.-E. P. in U. M. Zimmerman (Eds.), *Emerging Paradigms in Urban Mobility* (pp. 159–168). Elsevier. https://doi.org/10.1016/B978-0-12-811434-6.00008-1

Aguiléra, A. (2019). Smartphone and Individual Travel Behavior. In *Urban Mobility and the Smartphone* (pp. 1–37). Elsevier Inc. https://doi.org/10.1016/B978-0-12-812647-9.00001-9

Alessandrini, A., Campagna, A., Site, P. D., Filippi, F., & Persia, L. (2015). Automated Vehicles and the Rethinking of Mobility and Cities. *Transportation Research Procedia*, *5*, 145–160. https://doi.org/10.1016/j.trpro.2015.01.002

Alessandrini, A., Holguin, C., & Parent, M. (2018). ARTS Certification and Legal Framework. In *Implementing Automated Road Transport Systems in Urban Settings* (pp. 265–293). Elsevier. https://doi.org/10.1016/B978-0-12-812993-7.00005-X

Alfonso, J., Naranjo, J. E., Menéndez, J. M., & Alonso, A. (2018). Vehicular Communications. In *Intelligent Vehicles* (pp. 103–139). Elsevier. https://doi.org/10.1016/B978-0-12-812800-8.00003-5

Alves, M. (2017). Driven by Distraction: Sustainable Road Safety and the Impact of Autonomous Driving on Vulnerable Users (breakout presentation). *Journal of Transport & Health*, *7*, S65. https://doi.org/10.1016/j.jth.2017.11.105

Anania, E. C., Rice, S., Walters, N. W., Pierce, M., Winter, S. R., & Milner, M. N. (2018). The effects of positive and negative information on consumers' willingness to ride in a driverless vehicle. *Transport Policy*, *72*, 218–224. https://doi.org/10.1016/j.tranpol.2018.04.002

Anderson, S. (2017). Advancing Autonomy with LiDAR. *Automotive Design & Production*, *129*(6), 12.

Arena, F., & Pau, G. (2019). An Overview of Vehicular Communications. *Future Internet*, *11*(2), 27. https://doi.org/10.3390/fi11020027

Aria, E., Olstam, J., & Schwietering, C. (2016). Investigation of Automated Vehicle Effects on Driver's Behavior and Traffic Performance. *Transportation Research Procedia*, *15*, 761–770. https://doi.org/10.1016/j.trpro.2016.06.063

Armingol, J. M., Alfonso, J., Aliane, N., Clavijo, M., Campos-Cordobés, S., Escalera, A. de la, del Ser, J., Fernández, J., García, F., Jiménez, F., López, A. M., Mata, M., Martín, D., Menéndez, J. M., Sánchez-Cubillo, J., Vázquez, D., & Villalonga, G. (2018). Environmental Perception for Intelligent Vehicles. In *Intelligent Vehicles* (pp. 23–101). Elsevier. https://doi.org/10.1016/B978-0-12-812800-8.00002-3

Atzori, L., Floris, A., Girau, R., Nitti, M., & Pau, G. (2018). Towards the implementation of the Social Internet of Vehicles. *Computer Networks*, *147*, 132–145. https://doi.org/10.1016/j.comnet.2018.10.001

Babbar, S., & Lyons, S. (2017). *Market Forecast for connected and autonomous vehicles* (Issue July).

Bailey, K. D. (1994). *Typologies and Taxonomies: An Introduction to Classification Techniques* (Issue 102). SAGE Publications.

Bamonte, T. J. (2013). Drivers of Change. *TM&E Magazine*, 5–10.

Banchiri, B. (2016). ' Drive Me London ' will test Volvo ' s driverless cars in heavy congestion. *Financial Times*, 1–3.

Banks, V. A., Stanton, N. A., Burnett, G., & Hermawati, S. (2018). Distributed Cognition on the road: Using EAST to explore future road transportation systems. *Applied Ergonomics*, *68*(March 2017), 258–266. https://doi.org/10.1016/j.apergo.2017.11.013

Bansal, P., & Kockelman, K. M. (2017). Forecasting Americans' long-term adoption of connected and autonomous vehicle technologies. *Transportation Research Part A: Policy and Practice*, *95*, 49–63. https://doi.org/10.1016/j.tra.2016.10.013

Bansal, P., Kockelman, K. M., & Singh, A. (2016). Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. *Transportation Research Part C: Emerging Technologies*, *67*, 1–14. https://doi.org/10.1016/j.trc.2016.01.019

Barcelo, J. (2019). *Future Trends in Sustainable Transportation ´*. https://doi.org/10.1016/B978-0-12-814242-4.00016-8

Bechtsis, D., Tsolakis, N., Vlachos, D., & Srai, J. S. (2018). Intelligent Autonomous Vehicles in digital supply chains: A framework for integrating innovations towards sustainable value networks. *Journal of Cleaner Production*, *181*, 60–71. https://doi.org/10.1016/j.jclepro.2018.01.173

Bell, A. (2017). How Will Walking Survive the Driverless Car? (breakout presentation). *Journal of Transport & Health*, *7*(May), S64–S65. https://doi.org/10.1016/j.jth.2017.11.104

Bellotti, E. (2014). *Qualitative networks: Mixed methods in sociological research*. Routledge.

Bezai, N. E., Medjdoub, B., Al-Habaibeh, A., Chalal, M. L., & Fadli, F. (2021). Future cities and autonomous vehicles: analysis of the barriers to full adoption. *Energy and Built Environment*, *2*(1), 65–81. https://doi.org/10.1016/j.enbenv.2020.05.002

Bichiou, Y., & Rakha, H. A. (2018). Real-time optimal intersection control system for automated/cooperative vehicles. *International Journal of Transportation Science and Technology*, 1–12. https://doi.org/10.1016/j.ijtst.2018.04.003

Blumberg, B. (2008). *Business research methods* (D. R. Cooper & P. S. Schindler, Eds.; 2nd Europe). McGraw-Hill Education.

Bogdan, R., & Biklen, S. K. (1998). *Qualitative Research for Education: An Introduction to Theory and Methods*. Allyn and Bacon.

Bonnefon, J.-F., Shariff, A., & Rahwan, I. (2016). The social dilemma of autonomous vehicles. *Science*, *352*(6293), 1573–1576. https://doi.org/10.1126/science.aaf2654

Boutueil, V. (2019). New Mobility Services. In *Urban Mobility and the Smartphone* (pp. 39–78). Elsevier. https://doi.org/10.1016/B978-0-12-812647-9.00002-0

Brake. (2017). *Connected and autonomous vehicles | Brake*. https://www.brake.org.uk/get-involved/take-action/mybrake/knowledge-centre/vehicles/connected-and-autonomous-vehicles

British Parking association. (2016). *Motorists spend nearly four days a year looking for a parking space*. https://www.britishparking.co.uk/News/motorists-spend-nearly-four-days-a-year-looking-for-a-parking-space

Bryman, A. (2006). Integrating quantitative and qualitative research: how is it done? *Qualitative Research*, *6*(1), 97–113. https://doi.org/10.1177/1468794106058877

Buckley, L., Kaye, S. A., & Pradhan, A. K. (2018). A qualitative examination of drivers' responses to partially automated vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour*, *56*, 167–175. https://doi.org/10.1016/j.trf.2018.04.012

Cavoski, A. (2019). Potential risks for an electric vehicle future. *E-Law*.

Chen, D., Ahn, S., Chitturi, M., & Noyce, D. A. (2017). Towards vehicle automation: Roadway capacity formulation for traffic mixed with regular and automated vehicles. *Transportation Research Part B: Methodological*, *100*, 196–221. https://doi.org/10.1016/j.trb.2017.01.017

Chen, G., & Fraichard, T. (2007). A Real-Time Navigation Architecture for Automated Vehicles in Urban Environments. *2007 IEEE Intelligent Vehicles Symposium*, *JULY 2007*, 1223–1228. https://doi.org/10.1109/IVS.2007.4290285

Chen, M., Tian, Y., Fortino, G., Zhang, J., & Humar, I. (2018). Cognitive Internet of Vehicles. *Computer Communications*, *120*(October 2017), 58–70. https://doi.org/10.1016/j.comcom.2018.02.006

Chen, X., Ma, H., Wan, J., Li, B., & Xia, T. (2017). Multi-view 3D Object Detection Network for Autonomous Driving. *2017 IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 6526–6534. https://doi.org/10.1109/CVPR.2017.691

Cheong, H.-W., & Lee, H. (2018). Requirements of AGV (Automated Guided Vehicle) for SMEs (Small and Medium-sized Enterprises). *Procedia Computer Science*, *139*, 91–94. https://doi.org/10.1016/j.procs.2018.10.222

Choy, L. T. (2014). The strengths and weaknesses of research methodology: Comparison and complimentary between qualitative and quantitative approaches. *IOSR Journal of Humanities and Social Science*, *19*(4), 99–104.

Cohen, L., Manion, L., & Morrison, K. (2017). *Research Methods in Education*. Routledge.

Cohen, S. A., & Hopkins, D. (2019). Autonomous vehicles and the future of urban tourism. *Annals of Tourism Research*, *74*(September 2018), 33–42. https://doi.org/10.1016/j.annals.2018.10.009

Collis, J., & Hussey, R. (2014). *Business research : a practical guide for undergraduate and postgraduate students.* (4th editio). Palgrave Macmillan.

Combs, T. S., Sandt, L. S., Clamann, M. P., & McDonald, N. C. (2019). Automated Vehicles and Pedestrian Safety: Exploring the Promise and Limits of Pedestrian Detection. *American Journal of Preventive Medicine*, *56*(1), 1–7. https://doi.org/10.1016/j.amepre.2018.06.024

Conceição, L., Correia, G., & Tavares, J. P. (2017). The deployment of automated vehicles in urban transport systems: a methodology to design dedicated zones. *Transportation Research Procedia*, *27*, 230–237. https://doi.org/10.1016/j.trpro.2017.12.025

Congressional Research Service. (2018). *Issues in Autonomous Vehicle Deployment*.

Connelly, L. M. (2013). Limitation section. *MEDSURG Nursing*, *22*(5), 2013.

Consel, C., & Kabac, M. (2014). *Cities*. *March 2016*.

Creswell, J. W. (2013a). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Creswell, J. W. (2013b). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. In *Research design Qualitative quantitative and mixed methods approaches*. https://doi.org/10.1007/s13398-014-0173-7.2

Creswell, J. W., & Clark, V. L. P. (2007). *Designing and conducting mixed methods research* (pp. 58–88). SAGE Publications.

Crotty, M. (1998). The foundations of social research [electronic resource] : meaning and perspective in the research process. In *The foundations of social research : meaning and perspective in the research process*. SAGE.

Crovitz, L. G. (2014). *The Feds Stall Self-Driving Cars ; Regulatory delay causes real harm , as human error causes more than 90 % of car accidents .* 1–3.

De Bruyne, J., & Werbrouck, J. (2018). Merging self-driving cars with the law. *Computer Law & Security Review*, *34*(5), 1150–1153. https://doi.org/10.1016/j.clsr.2018.02.008

De La Torre, G., Rad, P., & Choo, K.-K. R. (2018). Driverless vehicle security: Challenges and future research opportunities. *Future Generation Computer Systems*. https://doi.org/10.1016/j.future.2017.12.041

De Silva, V., Roche, J., & Kondoz, A. (2017). *Fusion of LiDAR and Camera Sensor Data for Environment Sensing in Driverless Vehicles*.

Department for Transport. (2014). *Driverless cars: regulatory testing framework - GOV.UK*. https://www.gov.uk/government/consultations/driverless-cars-regulatory-testing-framework

Department for Transport. (2018). *Reported road casualties in Great Britain : 2017 annual report* (Issue September).

Dixon-Woods, M., Bonas, S., Booth, A., Jones, D. R., Miller, T., Sutton, A. J., Shaw, R. L., Smith, J. A., & Young, B. (2006). How can systematic reviews incorporate qualitative research? A critical perspective. *Qualitative Research*, *6*(1), 27–44. https://doi.org/10.1177/1468794106058867

Dubois, A., & Gadde, L.-E. (2002). Systematic combining: an abductive approach to case research. *Journal of Business Research*, *55*(7), 553–560. https://doi.org/10.1016/S0148-2963(00)00195-8

Easterby-Smith, M. (2008). *Management research* (R. Thorpe, P. Jackson, & M. Easterby-Smith, Eds.; 3rd ed..). SAGE.

Easterby-Smith, M., Thorpe, R., & Jackson, P. R. (2012). *Management Research*. SAGE Publications.

Economic and Social Council. (2014). Report of the sixty-eighth session of the Working Party on Road Traffic Safety. *Assembly*, *10329*(April), 1–11.

European Commission. (2017). *2016 road safety statistics: What is behind the figures? March*, 1–4.

Evas, T., Rohr, C., Dunkerley, F., & Howarth, D. (2018). A Common EU approach to liability rules and insurance for connected and autonomous vehicles. *EU Publications*, 200. https://doi.org/10.2861/282501

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice*, *77*, 167–181. https://doi.org/10.1016/j.tra.2015.04.003

Fagnant, D. J., & Kockelman, K. M. (2016). Dynamic ride-sharing and fleet sizing for a system of shared autonomous vehicles in Austin, Texas. *Transportation*, *45*(1), 143–158. https://doi.org/10.1007/s11116-016-9729-z

Ferrero, F., Perboli, G., Rosano, M., & Vesco, A. (2018). Car-sharing services: An annotated review. *Sustainable Cities and Society*, *37*(September 2017), 501–518. https://doi.org/10.1016/j.scs.2017.09.020

Fowler, F. J. (2009). *Survey Research Methods*. SAGE Publications.

Francis, E. (2012a). Driverless cars in 2022...making the vision a reality. *Automotive Industries AI*, *192*(4).

Francis, E. (2012b). Driverless cars in 2022⋯ making the vision a reality. *Automotive Industries AI*, *192*(4).

Furlong, P., & Marsh, D. (2010). A skin not a sweater: ontology and epistemology in political science. *Theory and Methods in Political Science*, 184–211.

Gallello, D. (2013). *Autonomous vehicle simulation*. Http://Www.Mscsoftware.Com/Sites/Default/Files/Autonomous-Vehicle-Simulation-Building-Blocks.Pdf. www.mscsoftware.com

Gao, T., & Xin, X. (2019). *Location Privacy Protection Scheme Based on Random Encryption Period in VANETs* (L. Barolli, F. Xhafa, N. Javaid, & T. Enokido, Eds.; pp. 366–374). Springer International Publishing. https://doi.org/10.1007/978-3-319-93554-6_34

Gerla, M., Lee, E.-K., Pau, G., & Lee, U. (2014). *Internet of Vehicles: From Intelligent Grid to Autonomous Cars and Vehicular Clouds*. 241–246. https://doi.org/10.1109/WF-IoT.2014.6803166

Gheorghiu, A., & Delhomme, P. (2018). For which types of trips do French drivers carpool? Motivations underlying carpooling for different types of trips. *Transportation Research Part A: Policy and Practice*, *113*(11), 460–475. https://doi.org/10.1016/j.tra.2018.05.002

Giering, M., Venugopalan, V., & Reddy, K. (2015). Multi-modal sensor registration for vehicle perception via deep neural networks. *2015 IEEE High Performance Extreme Computing Conference, HPEC 2015*. https://doi.org/10.1109/HPEC.2015.7322485

Godha, S. (2017). On-road obstacle detection system for driver assistance. *Asia Pacific Journal of Engineering Science and Technology*, *3*(1), 16–21.

Gopalswamy, S., & Rathinam, S. (2018). Infrastructure Enabled Autonomy: A Distributed Intelligence Architecture for Autonomous Vehicles. *2018 IEEE Intelligent Vehicles Symposium (IV)*, *2018-June*, 986–992. https://doi.org/10.1109/IVS.2018.8500436

Great Britain. Department for Transport. (2007). *Manual for streets.* Thomas Telford Pub.

Gruel, W., & Stanford, J. M. (2016). Assessing the Long-term Effects of Autonomous Vehicles: A Speculative Approach. *Transportation Research Procedia*, *13*, 18–29. https://doi.org/10.1016/j.trpro.2016.05.003

Grush, B., & Niles, J. (2018a). Barriers to Shared Use of Vehicles. In *The End of Driving* (pp. 125–139). Elsevier. https://doi.org/10.1016/B978-0-12-815451-9.00009-2

Grush, B., & Niles, J. (2018b). Transitioning Through Multiple Automated Forms. In *The End of Driving* (pp. 87–103). Elsevier. https://doi.org/10.1016/B978-0-12-815451-9.00006-7

Grush, B., Niles, J., & Baum, E. (2016). *Ontario Must Prepare for Vehicle Automation: Automated Vehicles Can Influence Urban Form, Congestion, and Infrastructure Delivery*. 76.

Guanetti, J., Kim, Y., & Borrelli, F. (2018). Control of connected and automated vehicles: State of the art and future challenges. *Annual Reviews in Control*, *45*(April), 18–40. https://doi.org/10.1016/j.arcontrol.2018.04.011

Guba, E. G., & Lincoln, Y. S. (1994). Competing Paradigms in Qualitative Research. *Handbook of Qualitative Research*, 105–117. https://doi.org/http://www.uncg.edu/hdf/facultystaff/Tudge/Guba%20&%20Lincoln%201994.pdf

Hachem, S., Issarny, V., Pozdnukhov, A., & Bhatia, R. (2015). *Urban Civics - Democratizing Urban Data for Healthy Smart Cities*. https://ercim-news.ercim.eu/en98/special/urban-civics-democratizing-urban-data-for-healthy-smart-cities

Hall, R. (2013). Mixed methods: In search of a paradigm. *L. Lê (Éd.), Conducting Research in a Changing and Challenging World*, 71–78.

Hitchcock, G. (1995). *Research and the teacher : a qualitative introduction to school-based research* (2nd ed..). Routledge.

HM Treasury. (2013). National Infrastructure Plan 2013. In *October* (Issue June).

Hodkinson, G. (2015). *Video | Films, animations, interviews, 3D visualisations by Arup - global engineers, planners, designers, technical consultants*. http://video.arup.com/?v=1_4icuqqhc

Hongyu, H., Chi, Z., Yuhuan, S., Bin, Z., & Fei, G. (2018). An Improved Artificial Potential Field Model Considering Vehicle Velocity for Autonomous Driving. *IFAC-PapersOnLine*, *51*(31), 863–867. https://doi.org/10.1016/j.ifacol.2018.10.095

Hörl, S., Ciari, F., & Axhausen, K. W. (2016). Recent perspectives on the impact of autonomous vehicles. *Arbeitsberichte Verkehrs- Und Raumplanung*, *1216*(September). https://doi.org/10.13140/RG.2.2.26690.17609

Hou, Z., & Gao, J. (2019). Safety message data transmission model and congestion control scheme in VANET. *International Journal of Information and Communication Technology*, *14*(2), 251. https://doi.org/10.1504/IJICT.2019.097691

Hussain, R., Bouk, S. H., Javaid, N., Khan, A. M., & Lee, J. (2018). Realization of VANET-Based Cloud Services through Named Data Networking. *IEEE Communications Magazine*, *56*(8), 168–175. https://doi.org/10.1109/MCOM.2018.1700514

Hyatt, N. (2017, April). *What happens when self-driving happens*. Spark Capital Collection. https://knowledge.sparkcapital.com/what-happens-when-self-driving-happens-f48f3b93f9ba

Hyde, K. F. (2000). Recognising deductive processes in qualitative research. *Qualitative Market Research: An International Journal*, *3*(2), 82–90. https://doi.org/10.1108/13522750010322089

Hyperdrive. (2020, May). *The State of the Self-Driving Car Race 2020*. https://www.bloomberg.com/features/2020-self-driving-car-race/

Jiménez, F. (2018). Introduction. In *Intelligent Vehicles* (pp. 1–20). Elsevier. https://doi.org/10.1016/B978-0-12-812800-8.00001-1

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher*, *33*(7), 14–26. https://doi.org/10.3102/0013189X033007014

Joiner, I. A. (2018). Driverless Vehicles. In *Emerging Library Technologies* (pp. 69–94). Elsevier. https://doi.org/10.1016/B978-0-08-102253-5.00006-X

Kaiwartya, O., Abdullah, A. H., Cao, Y., Altameem, A., Prasad, M., Lin, C.-T., & Liu, X. (2016). Internet of Vehicles: Motivation, Layered Architecture, Network Model, Challenges, and Future Aspects. *Access, IEEE*, *4*, 5356–5373.

Kala, R. (2016). 3 - Perception in Autonomous Vehicles. In R. Kala (Ed.), *On-Road Intelligent Vehicles* (pp. 36–58). Butterworth-Heinemann. https://doi.org/https://doi.org/10.1016/B978-0-12-803729-4.00003-9

Kala, R., & Warwick, K. (2013). Motion planning of autonomous vehicles in a non-autonomous vehicle environment without speed lanes. *Engineering Applications of Artificial Intelligence*, *26*(5–6), 1588–1601. https://doi.org/10.1016/j.engappai.2013.02.001

Kalra, N., & Paddock, S. M. (2016). Driving to safety: How many miles of driving would it take to demonstrate autonomous vehicle reliability? *Transportation Research Part A: Policy and Practice*, *94*, 182–193. https://doi.org/10.1016/j.tra.2016.09.010

Katrakazas, C., Quddus, M., Chen, W.-H., & Deka, L. (2015). Real-time motion planning methods for autonomous on-road driving: State-of-the-art and future research directions. *Transportation Research Part C: Emerging Technologies*, *60*, 416–442. https://doi.org/10.1016/j.trc.2015.09.011

Kaur, K., & Rampersad, G. (2018). Trust in driverless cars: Investigating key factors influencing the adoption of driverless cars. *Journal of Engineering and Technology Management*, *48*(April), 87–96. https://doi.org/10.1016/j.jengtecman.2018.04.006

Kharrazi, A., Qin, H., & Zhang, Y. (2016). *Urban Big Data and Sustainable Development Goals: Challenges and Opportunities*. https://doi.org/10.3390/su8121293

Kho, Y. H., Abdulla, A. E., & Yan, J. C. Z. (2014). A vision-based autonomous vehicle tracking robot platform. *Industrial Electronics & Applications (ISIEA), 2014 IEEE Symposium On*, 173–176.

Kim, J., Jo, K., Kim, D., Chu, K., & Sunwoo, M. (2013). Behavior and Path Planning Algorithm of Autonomous Vehicle A1 in Structured Environments. *IFAC Proceedings Volumes*, *46*(10), 36–41. https://doi.org/10.3182/20130626-3-AU-2035.00053

Kim, J., & Seo, B. S. (2013). How to calculate sample size and why. *Clinics in Orthopedic Surgery*, *5*(3).

Kim, S. (2018). Blockchain for a Trust Network Among Intelligent Vehicles. In *Blockchain Technology: Platforms, Tools and Use Cases* (1st ed., Vol. 111, pp. 43–68). Elsevier Inc. https://doi.org/10.1016/bs.adcom.2018.03.010

Kivunja, C., & Kuyini, A. B. (2017). Understanding and Applying Research Paradigms in Educational Contexts. *International Journal of Higher Education*, *6*(5), 26. https://doi.org/10.5430/ijhe.v6n5p26

Kolarova, V., Steck, F., Cyganski, R., & Trommer, S. (2018). Estimation of the value of time for automated driving using revealed and stated preference methods. *Transportation Research Procedia*, *31*, 35–46. https://doi.org/10.1016/j.trpro.2018.09.044

Konrad, T., Gehrt, J.-J., Lin, J., Zweigel, R., & Abel, D. (2018). Advanced state estimation for navigation of automated vehicles. *Annual Reviews in Control*, *46*, 181–195. https://doi.org/10.1016/j.arcontrol.2018.09.002

Kröger, L., Kuhnimhof, T., & Trommer, S. (2018). Does context matter? A comparative study modelling autonomous vehicle impact on travel behaviour for Germany and the USA. *Transportation Research Part A: Policy and Practice*, *xxxx*, 0–1. https://doi.org/10.1016/j.tra.2018.03.033

Krueger, R., Rashidi, T. H., & Rose, J. M. (2016). Preferences for shared autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, *69*, 343–355. https://doi.org/10.1016/j.trc.2016.06.015

Kyriakidis, M., Happee, R., & de Winter, J. C. F. (2015). Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. *Transportation Research Part F: Traffic Psychology and Behaviour*, *32*, 127–140. https://doi.org/10.1016/j.trf.2015.04.014

LaValley, M. P. (2008). Logistic Regression. *Circulation*, *117*(18), 2395–2399. https://doi.org/10.1161/CIRCULATIONAHA.106.682658

Levinson, J., Askeland, J., Becker, J., Dolson, J., Held, D., Kammel, S., Kolter, J. Z., Langer, D., Pink, O., Pratt, V., Sokolsky, M., Stanek, G., Stavens, D., Teichman, A., Werling, M., & Thrun, S. (2011). Towards fully autonomous driving: Systems and algorithms. *2011 IEEE Intelligent Vehicles Symposium (IV)*, *Iv*, 163–168. https://doi.org/10.1109/IVS.2011.5940562

LI, F., CHEN, W., Wang, J., SHUI, Y., YANG, K., XU, L., YU, J., & LI, C. (2018). Different Traffic Density Connectivity Probability Analysis in VANETs with Measured Data at 5.9 GHz. *2018 16th International Conference on Intelligent Transportation Systems Telecommunications (ITST)*, 1–7. https://doi.org/10.1109/ITST.2018.8566891

Li, J., Bao, H., Han, X., Pan, F., Pan, W., Zhang, F., & Wang, D. (2016). Real-time self-driving car navigation and obstacle avoidance using mobile 3D laser scanner and GNSS. *Multimedia Tools and Applications*, 1–23. https://doi.org/10.1007/s11042-016-4211-7

Li, S., Sui, P., Xiao, J., & Chahine, R. (2018). Policy formulation for highly automated vehicles: Emerging importance, research frontiers and insights. *Transportation Research Part A: Policy and Practice*, *xxxx*, 0–1. https://doi.org/10.1016/j.tra.2018.05.010

Liljamo, T., Liimatainen, H., & Pöllänen, M. (2018). Attitudes and concerns on automated vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour*, *59*, 24–44. https://doi.org/10.1016/j.trf.2018.08.010

Litman, T. (2003). Reinventing Transportation Exploring the Paradigm Shift Needed to Reconcile Transportation and Sustainability Objectives. *Transportation Research Record 1670*, 8–12. https://doi.org/10.1016/j.techfore.2010.09.005

Litman, T. (2017a). Autonomous Vehicle Implementation Predictions: Implications for Transport Planning. *Transportation Research Board Annual Meeting*, *42*(2017), 36–42. https://doi.org/10.1613/jair.301

Litman, T. (2017b). *Autonomous vehicle implementation predictions: Implications for Transport Planning*. Victoria Transport Policy Institute Victoria, Canada.

Liu, X., Jia, Z., Xu, E., & Gong, B. (2019). *Trusted Computing and Information Security* (H. Zhang, B. Zhao, & F. Yan, Eds.; Vol. 960). Springer Singapore. https://doi.org/10.1007/978-981-13-5913-2

Liu, Y., Wang, F., Dobaie, A. M., He, G., & Zhuang, Y. (2017). Comparison of 2D image models in segmentation performance for 3D laser point clouds. *Neurocomputing*, *251*, 136–144. https://doi.org/10.1016/j.neucom.2017.04.030

Lom, M., Pribyl, O., & Svitek, M. (2016). Industry 4.0 as a part of smart cities. *2016 Smart Cities Symposium Prague (SCSP)*, 1–6. https://doi.org/10.1109/SCSP.2016.7501015

López-Lambas, M. E. (2018). The Socioeconomic Impact of the Intelligent Vehicles. In *Intelligent Vehicles* (Issue iV, pp. 437–453). Elsevier. https://doi.org/10.1016/B978-0-12-812800-8.00011-4

Loukas, G., Karapistoli, E., Panaousis, E., Sarigiannidis, P., Bezemskij, A., & Vuong, T. (2019). A taxonomy and survey of cyber-physical intrusion detection approaches for vehicles. *Ad Hoc Networks*, *84*, 124–147. https://doi.org/10.1016/j.adhoc.2018.10.002

Luettel, T., Himmelsbach, M., & Wuensche, H.-J. (2012). Autonomous Ground Vehicles—Concepts and a Path to the Future. *Proceedings of the IEEE*, *100*(Special Centennial Issue), 1831–1839.

Mackenzie, N., & Knipe, S. (2006). Research Dilemmas: Paradigms, Methods and Methodology. *Issues in Educational Research*, *16*(2), 193–205.

MacNaughton, G., Rolfe, S. A., & Siraj-Blatchford, I. (2010). *Doing Early Childhood Research : International Perspectives on Theory and Practice*. Allen & Unwin.

Magnusson, P., Frank, H., Gustavsson, T., & Almkvist, E. (2019). Real-time high-resolution road condition map for the EU. In P. Pfeffer (Ed.), *9th International Munich Chassis Symposium 2018* (pp. 851–875). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-22050-1

Mahmassani, H. S. (2016). 50th Anniversary Invited Article—Autonomous Vehicles and Connected Vehicle Systems: Flow and Operations Considerations. *Transportation Science*, *50*(4), 1140–1162. https://doi.org/10.1287/trsc.2016.0712

Marks, J. (2018). *What Software Do Autonomous Vehicle Engineers Use? Part 1/2*. https://medium.com/@olley_io/what-software-do-autonomous-vehicle-engineers-use-part-1-2-275631071199

Marletto, G. (2019). Who will drive the transition to self-driving? A socio-technical analysis of the future impact of automated vehicles. *Technological Forecasting and Social Change*, *139*(September 2017), 221–234. https://doi.org/10.1016/j.techfore.2018.10.023

Martínez-Díaz, M., & Soriguera, F. (2018). Autonomous vehicles: theoretical and practical challenges. *Transportation Research Procedia*, *33*, 275–282. https://doi.org/10.1016/j.trpro.2018.10.103

Maurer, M., Gerdes, J. C., Lenz, B., & Winner, H. (2016). *Autonomous Driving* (M. Maurer, J. C. Gerdes, B. Lenz, & H. Winner, Eds.). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-48847-8

McNeill, P. (2005). *Research methods* (S. Chapman 1957-, Ed.; 3rd ed..).

McNeish, D. (2018). Thanks coefficient alpha, we'll take it from here. *Psychological Methods*, *23*(3), 412–433. https://doi.org/10.1037/met0000144

Meinlschmidt, G., Stalujanis, E., & Tegethoff, M. (2018). The psychobiology of using automated driving systems: A systematic review and integrative model. *Psychoneuroendocrinology*, *September*, 1–13. https://doi.org/10.1016/j.psyneuen.2018.09.029

Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation* (4th ed.). John Wiley & Sons.

Mertens, D. M. (1998). *Research methods in education and psychology : integrating diversity with quantitative and qualitative approaches*. Sage.

Mertens, D. M. (2007). Transformative Paradigm: Mixed Methods and Social Justice. *Journal of Mixed Methods Research*, *1*(3), 212–225.

Mertens, D. M. (2014). *Research and Evaluation in Education and Psychology: Integrating Diversity With Quantitative, Qualitative, and Mixed Methods* (4th ed.). SAGE Publications.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis : an expanded sourcebook* (2nd ed..). Sage.

Miles, T., & Graff, P. (2014). *Cars could drive themselves sooner than expected after European push*. http://uk.reuters.com/article/us-daimler-autonomous-driving-idUKKBN0DZ0UV20140519

Mohamad, M. M., Sulaiman, N. L., Sern, L. C., & Salleh, K. M. (2015). Measuring the Validity and Reliability of Research Instruments. *Procedia - Social and Behavioral Sciences*, *204*(November 2014), 164–171. https://doi.org/10.1016/j.sbspro.2015.08.129

Molnar, L. J., Ryan, L. H., Pradhan, A. K., Eby, D. W., St. Louis, R. M., & Zakrajsek, J. S. (2018). Understanding trust and acceptance of automated vehicles: An exploratory simulator study of transfer of control between automated and manual driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *58*, 319–328. https://doi.org/10.1016/j.trf.2018.06.004

Morse, J. M. (2000). Determining sample size. *Qualitative Health Research*, *10*(1), 3–5. https://doi.org/10.1177/104973200129118183

Müller, M., & Pfahl, D. (2008). Simulation Methods. In F. Shull, J. Singer, & D. I. K. Sjøberg (Eds.), *Guide to Advanced Empirical Software Engineering* (pp. 117–152). Springer London. https://doi.org/10.1007/978-1-84800-044-5_5

Mullins, G. E., Stankiewicz, P. G., Hawthorne, R. C., & Gupta, S. K. (2018). Adaptive generation of challenging scenarios for testing and evaluation of autonomous vehicles. *Journal of Systems and Software*, *137*, 197–215. https://doi.org/10.1016/j.jss.2017.10.031

Narayanan, A. (2019). When is it right and good for an intelligent autonomous vehicle to take over control (and hand it back)? *ArXiv E-Prints*.

Nath, S. V. (2017). IoT ARCHITECTURE. In *Internet of Things and Data Analytics Handbook* (pp. 239–249). John Wiley & Sons, Inc. https://doi.org/10.1002/9781119173601.ch14

Navarro, P., Fernández, C., Borraz, R., & Alonso, D. (2016). A Machine Learning Approach to Pedestrian Detection for Autonomous Vehicles Using High-Definition 3D Range Data. *Sensors*, *17*(12), 18. https://doi.org/10.3390/s17010018

Nazari, F., Noruzoliaee, M., & Mohammadian, A. K. (2018). Shared versus private mobility: Modeling public interest in autonomous vehicles accounting for latent attitudes. *Transportation Research Part C: Emerging Technologies*, *97*(November), 456–477. https://doi.org/10.1016/j.trc.2018.11.005

Neuendorf, K. A. (2016). *The Content Analysis Guidebook* (2nd ed.). SAGE Publications.

Nguyen, A., & Le, B. (2013). 3D point cloud segmentation: A survey. *2013 6th IEEE Conference on Robotics, Automation and Mechatronics (RAM)*, 225–230. https://doi.org/10.1109/RAM.2013.6758588

NHTSA. (2013). Summary for Policymakers. In Intergovernmental Panel on Climate Change (Ed.), *Climate Change 2013 - The Physical Science Basis* (pp. 1–30). Cambridge University Press. https://doi.org/10.1017/CBO9781107415324.004

Nordhoff, S., van Arem, B., & Happee, R. (2016). A Conceptual Model to Explain, Predict, and Improve User Acceptance of Driverless Podlike Vehicles. *Transportation Research Record: Journal of the Transportation Research Board*, *2602*(1), 60–67. https://doi.org/10.3141/2602-08

Nottinghamshire County Council. (2019). *Population estimates | Nottinghamshire County Council*.

Noy, I. Y., Shinar, D., & Horrey, W. J. (2018). Automated driving: Safety blind spots. *Safety Science*, *102*(March 2017), 68–78. https://doi.org/10.1016/j.ssci.2017.07.018

O'Leary, Z. (2017). *The essential guide to doing your research project* (3rd editio). SAGE Publications Ltd.

Panagiotopoulos, I., & Dimitrakopoulos, G. (2018). An empirical investigation on consumers' intentions towards autonomous driving. *Transportation Research Part C: Emerging Technologies*, *95*(September), 773–784. https://doi.org/10.1016/j.trc.2018.08.013

Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on Systems, Man, and Cybernetics. Part A, Systems and Humans : A Publication of the IEEE Systems, Man, and Cybernetics Society*, *30*(3), 286–297. https://doi.org/10.1109/3468.844354

Parry, T. (2019). Vehicle Licensing Statistics : Annual 2018. In *UK Department for Transport, Government Statistical Release* (Issue June).

Pathak, A., Issarny, V., & Holston, J. (2015). AppCivist - A Service-Oriented Software Platform for Socially Sustainable Activism. *Proceedings - International Conference on Software Engineering*, *2*, 515–518. https://doi.org/10.1109/ICSE.2015.185

Pau, G. (2013). Quickly Home Please: How Connected Vehicles Are Revolutionizing Road Transportation. *Internet Computing, IEEE*, *17*(1), 80–83.

Pendleton, S., Andersen, H., Du, X., Shen, X., Meghjani, M., Eng, Y., Rus, D., & Ang, M. (2017). Perception, Planning, Control, and Coordination for Autonomous Vehicles. *Machines*, *5*(1), 6. https://doi.org/10.3390/machines5010006

Peng, C.-Y. J., & So, T.-S. H. (2002). Logistic Regression Analysis and Reporting: A Primer. *Understanding Statistics*, *1*(1), 31–70. https://doi.org/10.1207/S15328031US0101_04

Perch, J. (2014). *Volvo's Magnetic Roads Might Make Self-driving Cars Viable*. http://expectattitude.com/technology/volvos-magnetic-roads-might-make-self-driving-cars-viable/

Pereira, M., Silva, D., Santos, V., & Dias, P. (2016). Self calibration of multiple LIDARs and cameras on autonomous vehicles. *Robotics and Autonomous Systems*, *83*(Supplement C), 326–337. https://doi.org/https://doi.org/10.1016/j.robot.2016.05.010

Pieroni, A., Scarpato, N., & Brilli, M. (2018). Industry 4.0 revolution in autonomous and connected vehicle a non-conventional approach to manage big data. *Journal of Theoretical and Applied Information Technology*, *96*(1), 10–18.

Potter, W. J., & Levine-Donnerstein, D. (1999). Rethinking validity and reliability in content analysis. *Journal of Applied Communication Research*, *27*(3), 258–284. https://doi.org/10.1080/00909889909365539

QSR international. (2019). *What is NVivo? | NVivo*. https://www.qsrinternational.com/nvivo/what-is-nvivo

Richards, D., & Stedmon, A. (2016). To delegate or not to delegate: A review of control frameworks for autonomous cars. *Applied Ergonomics*, *53*, 383–388. https://doi.org/10.1016/j.apergo.2015.10.011

Ricoeur, P. (1987). The Teleological and Deontological Structures of Action: Aristotle and/or Kant? *Royal Institute of Philosophy Lecture Series*, *21*, 99–111. https://doi.org/10.1017/S1358246100003507

Riggs, W., Larco, N., Tierney, G., Ruhl, M., Karlin-Resnick, J., & Rodier, C. (2019). Autonomous Vehicles and the Built Environment: Exploring the Impacts on Different Urban Contexts. In G. Meyer & S. Beiker (Eds.), *Road Vehicle Automation 5* (pp. 221–232). Springer International Publishing. https://doi.org/10.1007/978-3-319-94896-6_19

Roberts, C. (2017). TREADING CAREFULLY. In *Community Practitioner* (Vol. 90, Issue 11).

Robinson, D. (2019). *Meet the man who runs Nottingham's tram network - Nottinghamshire Live*. https://www.nottinghampost.com/news/nottingham-news/man-runs-nottingham-tram-532858

Robson, C. (2016). *Real world research*. John Wiley & Sons.

Rossman, G. B., & Wilson, B. L. (1985). Numbers and words combining quantitative and qualitative methods in a single large-scale evaluation study. *Evaluation Review*, *9*(5), 627–643.

Rubin, I., Baiocchi, A., Sunyoto, Y., & Turcanu, I. (2019). Traffic management and networking for autonomous vehicular highway systems. *Ad Hoc Networks*, *83*, 125–148. https://doi.org/10.1016/j.adhoc.2018.08.018

Rueckelt, T., Stavrakakis, I., Meuser, T., Brahmi, I. H., Böhnstedt, D., & Steinmetz, R. (2019). Data transmission plan adaptation complementing strategic time-network selection for connected vehicles. *Ad Hoc Networks*, *82*, 146–154. https://doi.org/10.1016/j.adhoc.2018.08.006

Ruggeri, K., Kácha, O., Menezes, I. G., Kos, M., Franklin, M., Parma, L., Langdon, P., Matthews, B., & Miles, J. (2018). In with the new? Generational differences shape population technology adoption patterns in the age of self-driving vehicles. *Journal of Engineering and Technology Management*, *50*(September 2017), 39–44. https://doi.org/10.1016/j.jengtecman.2018.09.001

Rusu, R. B., & Cousins, S. (2011). 3D is here: point cloud library. *IEEE International Conference on Robotics and Automation*, 1–4. https://doi.org/10.1109/ICRA.2011.5980567

Saini, I., Saad, S., & Jaekel, A. (2018). Identifying Vulnerabilities and Attacking Capabilities Against Pseudonym Changing Schemes in VANET. In I. Traore, I. Woungang, S. S. Ahmed, & Y. Malik (Eds.), *Intelligent, Secure, and Dependable Systems in Distributed and Cloud Environments* (pp. 1–15). Springer International Publishing. https://doi.org/10.1007/978-3-030-03712-3_1

Salahshoor, K., Mosallaei, M., & Bayat, M. (2008). Centralized and decentralized process and sensor fault monitoring using data fusion based on adaptive extended Kalman filter algorithm. *Measurement*, *41*(10), 1059–1076. https://doi.org/https://doi.org/10.1016/j.measurement.2008.02.009

Samsara. (2021). *The Next Wave in Safety Tech: Collision Avoidance Systems*. https://www.samsara.com/guides/collision-avoidance-system/

Santi, P., Resta, G., Szell, M., Sobolevsky, S., Strogatz, S. H., & Ratti, C. (2014). Quantifying the benefits of vehicle pooling with shareability networks. *Proceedings of the National Academy of Sciences*, *111*(37), 13290–13294. https://doi.org/10.1073/pnas.1403657111

Sapsford, R., & Jupp, V. (2006). *Data collection and analysis* (2nd Edditi). SAGE Publications Ltd. https://doi.org/10.4135/9781849208802

Sarantakos, S. (2012). *Social Research* (4th editio). Palgrave Macmillan.

Sarikan, S. S., Ozbayoglu, A. M., & Zilci, O. (2017). Automated Vehicle Classification with Image Processing and Computational Intelligence. *Procedia Computer Science*, *114*, 515–522. https://doi.org/10.1016/j.procs.2017.09.022

Saunders, M., Lewis, P., & Thornhill, A. (2008). Research Methods for Business Students. *Research Methods for Business Students*, 649. https://doi.org/10.1007/s13398-014-0173-7.2

Saunders, M. N. K. (2009). *Research methods for business students* (5th ed..). Financial Times Prentice Hall.

Schellekens, M. (2015). Self-driving cars and the chilling effect of liability law. *Computer Law & Security Review*, *31*(4), 506–517. https://doi.org/10.1016/j.clsr.2015.05.012

Schneble, C. O., & Shaw, D. M. (2021). Driver's views on driverless vehicles: Public perspectives on defining and using autonomous cars. *Transportation Research Interdisciplinary Perspectives*, *11*, 100446. https://doi.org/10.1016/j.trip.2021.100446

Schwab, K. (2017). *The Fourth Industrial Revolution*. Penguin Books Limited.

Schwarz, B. (2010). Lidar: Mapping the world in 3D. *Nature Photonics*, *4*(7), 429–430.

Scotland, J. (2012). Exploring the Philosophical Underpinnings of Research: Relating Ontology and Epistemology to the Methodology and Methods of the Scientific, Interpretive, and Critical Research Paradigms. *English Language Teaching*, *5*(9), 9–16. https://doi.org/10.5539/elt.v5n9p9

Shin, Y., Choi, H.-S., Nam, Y., & Lee, E. (2018). Efficient Data Delivery Protocol Using Vehicle Mobility Information in VANETs. *2018 Tenth International Conference on Ubiquitous and Future Networks (ICUFN)*, *2018-July*, 644–649. https://doi.org/10.1109/ICUFN.2018.8436668

Signifredi, A., Luca, B., Coati, A., Medina, J. S., & Molinari, D. (2015). A General Purpose Approach for Global and Local Path Planning Combination. *2015 IEEE 18th International Conference on Intelligent Transportation Systems*, 996–1001. https://doi.org/10.1109/ITSC.2015.166

Simoni, M. D., Kockelman, K. M., Gurumurthy, K. M., & Bischoff, J. (2018). Congestion pricing in a world of self-driving vehicles: an analysis of different strategies in alternative future scenarios. *Transportation Research Part C: Emerging Technologies*, *98*(December 2018), 1–26. https://doi.org/S0968090X1830370X

Skeete, J. (2018). Level 5 autonomy: The new face of disruption in road transport. *Technological Forecasting and Social Change*, *134*(October 2017), 22–34. https://doi.org/10.1016/j.techfore.2018.05.003

Sofaer, S. (1999). Qualitative methods: what are they and why use them? *Health Services Research*, *34*(5 Pt 2), 1101–1118.

Soltani, A. (2017). Social and urban form determinants of vehicle ownership; evidence from a developing country. *Transportation Research Part A: Policy and Practice*, *96*, 90–100. https://doi.org/10.1016/j.tra.2016.12.010

Song, C., Zhang, M., Jia, Z., Peng, W., & Guo, H. (2018). A lightweight batch anonymous authentication scheme for VANET based on pairing-free. *Computer Science and Information Systems*, *15*(3), 549–567. https://doi.org/10.2298/CSIS171222022S

Spears, D. (2019). *What Is Mobility on Demand and How Will It Shape the Future?* https://www.ecolane.com/blog/what-is-mobility-on-demand-and-how-will-it-shape-the-future

Stemler, S. (2001). An overview of content analysis. *Practical Assessment, Research and Evaluation*, *7*(17), 137–146.

Stern, R. E., Cui, S., Delle Monache, M. L., Bhadani, R., Bunting, M., Churchill, M., Hamilton, N., Haulcy, R., Pohlmann, H., Wu, F., Piccoli, B., Seibold, B., Sprinkle, J., & Work, D. B. (2018). Dissipation of stop-and-go waves via control of autonomous vehicles: Field experiments. *Transportation Research Part C: Emerging Technologies*, *89*(April 2017), 205–221. https://doi.org/10.1016/j.trc.2018.02.005

Straub, E. R., & Schaefer, K. E. (2018). It takes two to Tango: Automated vehicles and human beings do the dance of driving – Four social considerations for policy. *Transportation Research Part A: Policy and Practice*, *xxxx*, 0–1. https://doi.org/10.1016/j.tra.2018.03.005

Sucasas, V., Saghezchi, F. B., Radwan, A., Marques, H., Rodriguez, J., Vahid, S., & Tafazolli, R. (2015). Efficient privacy preserving security protocol for VANETs with sparse infrastructure deployment. *2015 IEEE International Conference on Communications (ICC)*, *2015-Septe*(333020), 7047–7052. https://doi.org/10.1109/ICC.2015.7249450

Sun, W., Zheng, J., & Liu, H. X. (2017). A capacity maximization scheme for intersection management with automated vehicles. *Transportation Research Procedia*, *23*(8), 121–136. https://doi.org/10.1016/j.trpro.2017.05.008

SurveyMonkey Inc. (2018). *Sample Size Calculator: Understanding Sample Sizes | SurveyMonkey*. https://www.surveymonkey.com/mp/sample-size-calculator/?utm_expid=.cOMQLyyUQhqbVct5bsJlAA.0&utm_referrer=https%3A%2F%2Fwww.google.co.uk%2F

Szajnfarber, Z., & Gralla, E. (2017). Qualitative methods for engineering systems: Why we need them and how to use them. *Systems Engineering*, *20*(6), 497–511. https://doi.org/10.1002/sys.21412

Szigeti, S., Csiszár, C., & Földes, D. (2017). Information Management of Demand-responsive Mobility Service Based on Autonomous Vehicles. *Procedia Engineering*, *187*, 483–491. https://doi.org/https://doi.org/10.1016/j.proeng.2017.04.404

Tabachnick, B. G., & Fidell, L. S. (2013). *Using Multivariate Statistics: Pearson New International Edition*. Pearson Education Limited.

Tas, O. S., Kuhnt, F., Zollner, J. M., & Stiller, C. (2016). Functional system architectures towards fully automated driving. *2016 IEEE Intelligent Vehicles Symposium (IV)*, *2016-Augus*(Iv), 304–309. https://doi.org/10.1109/IVS.2016.7535402

Tashakkori, A., & Teddlie, C. (2010). Sage handbook of mixed methods in social & behavioral research. In *Handbook of mixed methods in social & behavioral research* (2nd ed..). SAGE.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Teichman, A., & Thrun, S. (2011). Practical object recognition in autonomous driving and beyond. *Proceedings of IEEE Workshop on Advanced Robotics and Its Social Impacts, ARSO*, 35–38. https://doi.org/10.1109/ARSO.2011.6301978

The House of Lords Science and Technology Committee. (2017). Connected and Autonomous Vehicles: The future? - Science and Technology Committee. In *2nd Report of Session 2016–17* (Issue March).

Transport, D. for. (2007). Manual for Streets. In *Published by Thomas Telford Publishing, Published for the Department for Transport under licence from the Controller of Her Majesty's Stationery Office*.

Uçar, A., Demir, Y., & Güzeliş, C. (2017). Object recognition and detection with deep learning for autonomous driving applications. *Simulation*, *93*(9). https://doi.org/10.1177/0037549717709932

United Nations Conference on Road and Motor Transport. (1968). Vienna Convention on Road Traffic. *Vienna Convention on Road Traffic*, *1968*(NOVEMBER 1968), 1–78. https://doi.org/E/CONF.56/16/Rev.1/Amend.1

Urry, J. (2013). *What happens " after the car "? 44*(0), 1–4.

Vahidi, A., & Sciarretta, A. (2018). Energy saving potentials of connected and automated vehicles. *Transportation Research Part C: Emerging Technologies*, *95*(April), 822–843. https://doi.org/10.1016/j.trc.2018.09.001

Velodyne LiDAR. (2017). *Velodyne LiDAR HDL-64E S3 High Definition Real-Time 3D LiDAR*. http://velodynelidar.com/docs/datasheet/63-9194_Rev-F_HDL-64E_S3_Data Sheet_Web.pdf

Villagra, J., Acosta, L., Artuñedo, A., Blanco, R., Clavijo, M., Fernández, C., Godoy, J., Haber, R., Jiménez, F., Martínez, C., Naranjo, J. E., Navarro, P. J., Paúl, A., & Sánchez, F. (2018).

Automated Driving. In F. Jiménez (Ed.), *Intelligent Vehicles* (pp. 275–342). Elsevier. https://doi.org/10.1016/B978-0-12-812800-8.00008-4

Vogt, W. P. (2008). The Dictatorship of the Problem: Choosing Research Methods. *Methodological Innovations*, *3*(1), 1–17.

Wadud, Z. (2017). Fully automated vehicles: A cost of ownership analysis to inform early adoption. *Transportation Research Part A: Policy and Practice*, *101*, 163–176. https://doi.org/10.1016/j.tra.2017.05.005

Wadud, Z., MacKenzie, D., & Leiby, P. (2016). Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. *Transportation Research Part A: Policy and Practice*, *86*, 1–18. https://doi.org/10.1016/j.tra.2015.12.001

Wahid, A., Yasmeen, H., Shah, M. A., Alam, M., & Shah, S. C. (2019). Holistic approach for coupling privacy with safety in VANETs. *Computer Networks*, *148*, 214–230. https://doi.org/10.1016/j.comnet.2018.08.017

Wang, S., Deng, Z., & Yin, G. (2016). An Accurate GPS-IMU/DR Data Fusion Method for Driverless Car Based on a Set of Predictive Models and Grid Constraints. *Sensors*, *16*(3), 280. https://doi.org/10.3390/s16030280

Wang, Y., Ding, Y., Wu, Q., Wei, Y., Qin, B., & Wang, H. (2018). Privacy-Preserving Cloud-based Road Condition Monitoring with Source Authentication in VANETs. *IEEE Transactions on Information Forensics and Security*, *PP*(c), 1–1. https://doi.org/10.1109/TIFS.2018.2885277

Ward, M., Grinstein, G. G., & Keim, D. (2010). Human Perception and Information Processing. In *Interactive Data Visualization: Foundations, Techniques, and Applications* (pp. 73–128). Natick, Mass, A K Peters.

Webb, J., Wilson, C., & Kularatne, T. (2019). Will people accept shared autonomous electric vehicles? A survey before and after receipt of the costs and benefits. *Economic Analysis and Policy*, *61*, 118–135. https://doi.org/10.1016/j.eap.2018.12.004

Wiles, R., Crow, G., Heath, S., & Charles, V. (2008). The Management of Confidentiality and Anonymity in Social Research. *International Journal of Social Research Methodology*, *11*(5), 417–428. https://doi.org/10.1080/13645570701622231

Winter, S. R., Keebler, J. R., Rice, S., Mehta, R., & Baugh, B. S. (2018). Patient perceptions on the use of driverless ambulances: An affective perspective. *Transportation Research Part F: Traffic Psychology and Behaviour*, *58*, 431–441. https://doi.org/10.1016/j.trf.2018.06.033

wsp. (2016). *Adapting Infrastructure for a Driverless Future | WSP*. https://www.wsp.com/en-GL/insights/adapting-infrastructure-for-a-driverless-future

Xiaozhi, C., Huimin, M., Ji, W., Bo, L., & Tian, X. (2017). *(13) Multi-View 3D Object Detection Network for Autonomous Driving | Spotlight 4-2B - YouTube*. ComputerVisionFoundation Videos. https://www.youtube.com/watch?v=ChkgSvxAvMg

Xu, L. Da, & Duan, L. (2019). Big data for cyber physical systems in industry 4.0: a survey. *Enterprise Information Systems*, *13*(2), 148–169. https://doi.org/10.1080/17517575.2018.1442934

Xu, L. Da, Xu, E. L., & Li, L. (2018). Industry 4.0: state of the art and future trends. *International Journal of Production Research*, *56*(8), 2941–2962. https://doi.org/10.1080/00207543.2018.1444806

Xu, Z., Zhang, K., Min, H., Wang, Z., Zhao, X., & Liu, P. (2018). What drives people to accept automated vehicles? Findings from a field experiment. *Transportation Research Part C: Emerging Technologies*, *95*(June), 320–334. https://doi.org/10.1016/j.trc.2018.07.024

Yang, P., & Deng, L. (2018). An Effective Privacy Protection Mechanism in VANETs. *Proceedings of the 11th EAI International Conference on Mobile Multimedia Communications*, 39–44.

Yauch, C. A., & Steudel, H. J. (2003). Complementary Use of Qualitative and Quantitative Cultural Assessment Methods. *Organizational Research Methods*, *6*(4), 465–481. https://doi.org/10.1177/1094428103257362

Yin, R. K. (2013). *Case study research: Design and methods*. Sage publications.

Young, A., Dickinson, P., Smart, J., Proctor, S., Castell, B., & White, B. (2010). Manual for Streets 2. In *Chartered Institution of Highways & Transportation*.

Zhang, S., Deng, W., Zhao, Q., Sun, H., & Litkouhi, B. (2013). Dynamic trajectory planning for vehicle autonomous driving. *Proceedings - 2013 IEEE International Conference on Systems, Man, and Cybernetics, SMC 2013*, 4161–4166. https://doi.org/10.1109/SMC.2013.709

Zhang, W. (2010). LIDAR-based road and road-edge detection. *Intelligent Vehicles Symposium (IV), 2010 IEEE*, 845–848.

Zhao, G., Xiao, X., Yuan, J., & Ng, G. W. (2014). Fusion of 3D-LIDAR and camera data for scene parsing. *Journal of Visual Communication and Image Representation*, *25*(1), 165–183. https://doi.org/https://doi.org/10.1016/j.jvcir.2013.06.008

Zhao, W., Ngoduy, D., Shepherd, S., Liu, R., & Papageorgiou, M. (2018). A platoon based cooperative eco-driving model for mixed automated and human-driven vehicles at a signalised intersection. *Transportation Research Part C: Emerging Technologies*, *95*(April), 802–821. https://doi.org/10.1016/j.trc.2018.05.025

Zhou, Y., Li, H., Shi, C., Lu, N., & Cheng, N. (2018). A Fuzzy-Rule Based Data Delivery Scheme in VANETs with Intelligent Speed Prediction and Relay Selection. *Wireless Communications and Mobile Computing*, *2018*, 1–15. https://doi.org/10.1155/2018/7637059

Zikmund, W. G. author. (2013). *Business research methods* (B. J. Babin, J. C. Carr, & M. Griffin, Eds.; Ninth edit). South-Western.

Appendices

Appendix 1

Autonomous cars adaptation in urban spaces (Barriers, Vehicle specifications and required Infrastructure)

Survey participation invitation

Dear participant,

My name is Nacer Eddine Bezai; I am a PhD student at the School of Architecture at Nottingham Trent University in the United Kingdom. My research project is "An adaptive urban planning framework to support autonomous Vehicles (AVs) technologies".

You are invited to participate in this research because your opinions will contribute to this research significantly. Therefore, I would be thankful if you take an interest in participating in this brief survey. It is essential to understand the purpose of this project so please take time to read the scope of the study and aim of the research. Moreover, please do not hesitate to contact us for further clarification and information.

This research aims to explore the potential of autonomous cars and develop a more adapted urban design model to assist planners, citizens, politicians, and stakeholders in their planning decision-making. However, the results that will be obtained from this survey will address the First and second objectives of the whole research, which are seeking to give answers about the barriers and obstacles preventing the adoption of Autonomous vehicles as well as the vehicle specifications.

In addition, the information provided by you will be kept confidentially, and they will not identify you in any report. Likewise, your organisation will not be determined. All the data gathered from this survey will be stored in a secured computer with a protected password. The data is shared in an anonymous style which allows being reused by other researchers and education purposes.

You will not be recorded in any other forms except the information that you will provide on with this survey.

If you would like to receive a copy of this survey's results, Please do not hesitate to contact us to put you on the circulation list. The ethical approval for this study has been granted by the Joint Inter College Ethics Committee of Nottingham Trent University.

Thank you very much for taking part in this study.

For further information

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Section I: Research purpose and Personal information

The Scope of the study

Increasing congestion on our roads today impose upon authorities to expand existing infrastructure due to its insufficiency or consider other possibilities to overcome such challenges. Besides, 90% of road accidents are due to human causes [1], [2]. According to the European commission fact sheet for 2016 on road safety, 46% of deaths are caused by cars [3].
On the other hand, Recently, the field of computers, sensors and automation have witnessed a high speed of development, which led to the rapid growth of autonomous vehicles technologies and manufacturers race which is thought to provide a radical change on the way people move, cities planning and safety [4].

Thus, this survey has the objective to investigate the barriers and vehicle specifications that prevent the adoption of fully autonomous vehicles (AVs). Therefore, knowing such obstacles and spec will assist in building up a framework to support planners, authorities and citizens to adopt such an inevitable upcoming technology.

Why you have been selected for this study:
This survey includes three major points of views ranging from City planners (various disciplines), Vehicles' manufacturers and authorities (city council). Consequently, based on your experience and important role that you play in your industry, you have been selected to participate in this investigation. This research is led by Nottingham Trent University to gather experts' opinions to establish barriers and vehicles speciation's framework. Your collaboration is exceptionally critical to contribute to generating Urban guidelines for AVs.

1. Participant's Personal Information

Name	
Job Title	
Area of expertise	
Years of expertise	
Email Address	

Section II:Obstacles through technology perspective

Figure1. Explains the AVs framework system which is divided into Sensor interface, communication, perception, Planning and, control and actuator. Nevertheless, they are combined with possible barriers preventing them to a fully autonomous level.
This phase of research will centre fundamentally around the assessment of the above framework keeping in mind that is valid, legitimate and dependable. The different opinions obtained from several experts will play a significant role in defining the desired final structure.

The below framework has two main section; Technical/technological aspects and social/cultural aspects. The former explains in depth the process which an AV can operate as well as the several technologies needed to be embedded in the vehicle. Whereas, the latter clarifies the barriers that AVs will face from social and cultural perspectives along with their possible impacts.

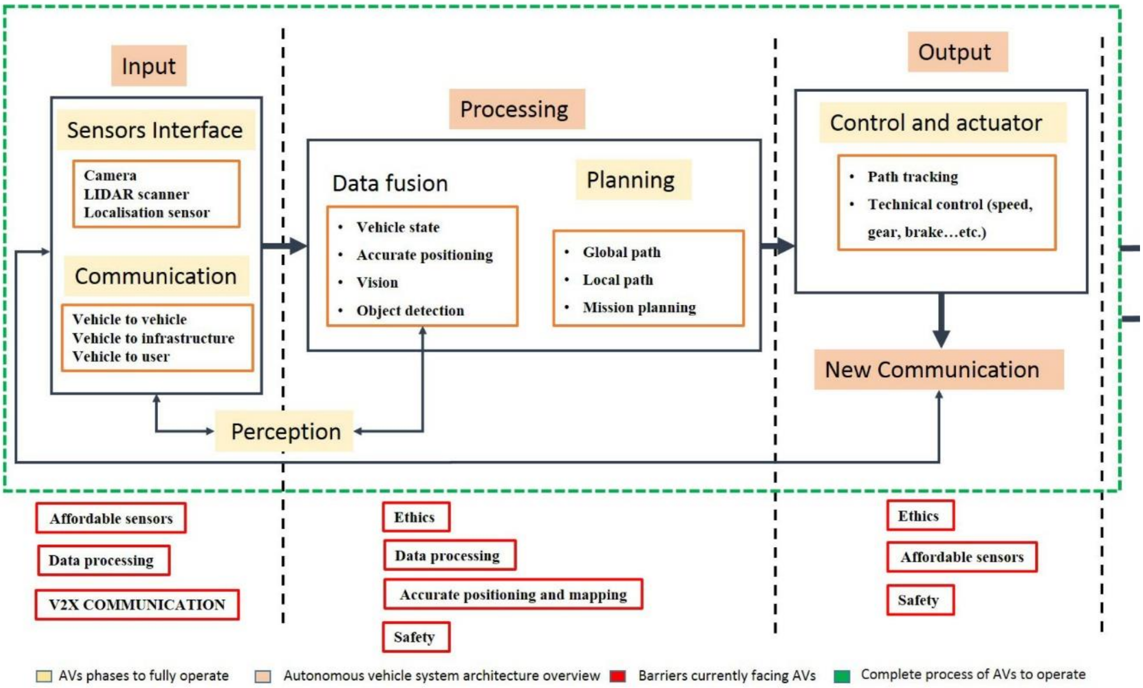

Figure 1. AVs framework system architecture overview combined with possible obstacles.

2. Generally speaking, what do you think are the barriers that prevent having Autonomous vehicles on our roads?

3. A part of the needed technology that must be in the vehicle, what do you think are the other obstacles?

4. To what extent do you agree or disagree with the substance of the proposed Framework?

- Extremely agree
- Moderately agree
- Slightly agree
- Neither agree nor disagree
- Slightly disagree
- Moderately disagree
- Extremely disagree

5. Does this Framework has shown too many, too few, or about the right barriers and vehicle specifications?

- Much too many
- Somewhat too many
- Slight too many
- About the right number
- Slightly too few
- Somewhat too few
- Much too few

6. How do you rate the following barriers based on their level of importance to resolve?

	Extremely important	Very Important	Moderately Important	Slightly Important	Not important at all	Remove this category
Data processing (Computer software and hardware)						
Safety						
Affordable sensors						
V2X communication						
Accurate positioning and mapping						
User acceptance and reaction						
Ethics						

7. How do you rate the following criteria (rank with 1 being the most important, and 7 being the least important)?

Please don't select more than 1 answer(s) per row.

Please don't select more than 1 answer(s) in any single column.

	1	2	3	4	5	6	7
Data processing (Computer software and hardware)	☐	☐	☐	☐	☐	☐	☐
Safety	☐	☐	☐	☐	☐	☐	☐
Affordable sensors	☐	☐	☐	☐	☐	☐	☐
V2X communication	☐	☐	☐	☐	☐	☐	☐
Accurate positioning and mapping	☐	☐	☐	☐	☐	☐	☐
User acceptance and reaction	☐	☐	☐	☐	☐	☐	☐
Ethics	☐	☐	☐	☐	☐	☐	☐

8. Do you think there are more barriers and vehicle specifications to be investigated either with a direct or indirect effect?

- ○ Yes
- ○ No
- ○ I am not sure
- ○ Other

8.a. If you selected Other, please specify:

9. When do you expect Autonomous vehicles will be entirely operating (Fully autonomous level) in our roads?

- ○ 0-5 Years
- ○ 6-10 Years
- ○ 11-15 Years
- ○ 16-29 Years
- ○ after 30 Years
- ○ Other

9.a. If you selected Other, please specify:

10. AVs have to be developed and looked at from three domains most: Manufacturers, city planning (various disciplines) and regulations; which of the previous do you think is needed to be developed firstly?

- ○ Regulations
- ○ City Planning
- ○ Vehicle Manufacturing
- ○ Other

10.a. If you selected Other, please specify:

Section III: STREET AND ROADS DESIGN

Streets and roads occupy three-quarters of public spaces According to Young et al. (2010) the design of the former have a considerable influence on the quality of individuals' lives. Thus, from this point, AVs adaptation will affect the three-quarters occupation.
As a fact Manual for street (MFS) either 1 or 2 have always focused on putting pedestrians at the top priority in urban areas. Nevertheless, other criteria have been taken such as applying a user hierarchy, design to keep speed limits below 20mph in places with a high density of pedestrians, encouraging innovations…etc. For full criteria, please see MFS principles.

The following journey from Point A (Market square; Starbucks coffee) to point B (Nottingham Trent University: Arkwright building) shows the path a vehicle undertakes. To access the journey via Google Map, please click on the link below.
https://www.google.co.uk/maps/dir/Starbucks+Coffee,+1+S+Parade,+Nottingham+NG1+2JS/52.9577963,-1.152225/@52.9544863,-1.1451327,571a,35y,270h,39.28t/data=!3m1!1e3!4m9!4m8!1m5!1m1!1s0x4879a6b2b02d88f3:0x31ec96cd43024d9f!2m2!1d-1.1505199!2d52.9528686!1m0!3e0?hl=en

Figure2. The journey from Point A (Market square; Starbucks coffee) to point B (Nottingham Trent University: Arkwright building)

11. Considering the vehicle is fully autonomous, what do you think, which of the following design principles and detailed design issues will be ***affected***?

- ☐ Zebra cross
- ☐ On-street parking
- ☐ Off-street parking
- ☐ Load and go (Drop points)

- Traffic lights
- Road signs
- Roadsides (1lane, 2 lanes or >3)
- Road separation
- Roundabout/intersection
- Islands
- Charging points
- One way/ two ways
- Restricted ways
- Other

11.a. If you selected Other, please specify:

12. Considering the vehicle is fully autonomous, what do you think, which of the following design principles and detailed design issues will be ***removed***?

- Zebra cross
- On-street parking
- Off-street parking
- Load and go (Drop points)
- Traffic lights
- Road signs
- Roadsides (1lane, 2 lanes or >3)
- Road separation
- Roundabout/intersection
- Islands
- Charging points
- One way/ two ways
- Restricted ways
- Other

12.a. If you selected Other, please specify:

13. Considering AVs fully autonomous level and MFS guidelines for design, how do you think the following design guidance will be affected?

	Extremely affected	Moderately affected	Slightly affected	I am not sure	No effect at all
Layout and connectivity	○	○	○	○	○
Quality of place	○	○	○	○	○
Street user's needs	○	○	○	○	○
Street geometry	○	○	○	○	○
Parking	○	○	○	○	○

Traffic sign and markings	○	○	○	○	○
Street furniture and lighting	○	○	○	○	○

14. Do you think Autonomous vehicles will affect the number of cars?

Statistics have shown tremendous growth in cars ownership (Conventional cars). 6.2 billion trips estimated to be taken by private vehicles in 2025 which 50% of them are urban trips that are doubled compared to 2005 [6].

- ○ Increase
- ○ Decrease
- ○ Neither
- ○ Other

14.a. If you selected Other, please specify:

15. In the case of Autonomous vehicles are not used for instance at night or specific times, where do you think they should be stored?

- ○ Existing parking in the city
- ○ Use the parking of different shopping centres such as ASDA, TESCO...etc.
- ○ Create underground/overground hubs parking particularly for AVs
- ○ Other

15.a. If you selected Other, please specify:

16. In relation to Q15, in case of creating specific parking (Hubs) For AVs, where do you think they should be located?

- ○ In the city centres
- ○ In each neighbourhood
- ○ In the outskirts
- ○ Other

16.a. If you selected Other, please specify:

17. Where do you think Autonomous vehicles (Fully automation) should be implemented firstly?

- Motorways (Connecting cities)
- Main roads (connecting city parts)
- Secondary roads
- Everywhere
- Other

17.a. If you selected Other, please specify:

18. In the future, Do you think after full adoption of Autonomous vehicles Manual driving should be banned?

- Yes
- No
- Other

18.a. If you selected Other, please specify:

19. Please, you can use this comment box for any comments or suggestions you would like to add.

References

[1] L. G. Crovitz, "The Feds Stall Self-Driving Cars ; Regulatory delay causes real harm, as human error causes more than 90 % of car accidents .," pp. 1–3, 2014.

[2] D. Richards and A. Stedmon, "To delegate or not to delegate: A review of control frameworks for autonomous cars," Appl. Ergon., vol. 53, pp. 383–388, 2016.

[3] European Commission, "2016 road safety statistics: What is behind the figures?," no. March, pp. 1–4, 2017.

[4] D. J. Fagnant and K. Kockelman, "Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations," Transp. Res. Part A Policy Pract., vol. 77, pp. 167–181, 2015.

[5] A. Young, P. Dickinson, J. Smart, S. Proctor, B. Castell, and B. White, Manual for Streets 2. 2010.

[6] A. Soltani, "Social and urban form determinants of vehicle ownership; evidence from a developing country," Transp. Res. Part A Policy Pract., vol. 96, pp. 90–100, 2017.

Appendix 2

NOTTINGHAM TRENT UNIVERSITY

Autonomous vehicles and users points of view

Survey participation invitation

Dear participant,

My name is Nacer Eddine Bezai; I am a PhD student at the School of Architecture at Nottingham Trent University in the United Kingdom. My research project is "An adaptive urban planning framework to support autonomous cars technologies".

You are invited to participate in this research because your opinions will contribute to this research significantly. Therefore, I would be thankful if you take an interest in participating in this brief survey. It is essential to understand the purpose of this project so please take time to read the scope of the study and aim of the research. Moreover, please do not hesitate to contact us for further clarification and information.

This research aims to explore the potential of autonomous cars and measure to what extent they will affect the users' behaviour. This survey is conducted to collect various opinions regarding Autonomous vehicles. Your contribution is exceptionally significant to the success of this study by identifying Users behaviour, acceptance and reaction to Autonomous cars.

Besides, the information provided by you will be kept confidentially, and they will not identify you in any report. Likewise, your organisation will not be defined. All the data gathered from this survey will be stored in a secured computer with a protected password. The data is shared in an anonymous style which allows being reused by other researchers and education purposes.

You will not be recorded in any other forms expect the information that you will provide on with this survey.

If you would like to receive a copy of this survey's results, Please do not hesitate to contact us to put you on the circulation list. The ethical approval for this study has been granted by the Joint Inter College Ethics Committee of Nottingham Trent University.

Thank you very much for taking part in this study.

For further information
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The Scope of the study

"Autonomous vehicles."

It is believed that since the internet, AVs will be the most substantial change and transition that will happen to societies. AVs will change driving Manners, traffic patterns and city planning, also, they will promote expected and unexpected new services. Whether people will use private or shared autonomous cars, the efficiency of them will decrease the number of vehicles on the street and the need for numerous city parking. Consequently, this opportunity will free up a lot of properties and land to be used as parks or green spaces. Hence, cities could be greener and sustainable. The possibility of adopting AVs will have the potential of reducing car ownership.

Section 1: Conventional cars VS Autonomous Vehicles

1. How do you usually travel (move) around the city?

- ☐ Private Car
- ☐ Taxi
- ☐ Bus
- ☐ Bicycle
- ☐ Tram
- ☐ Train
- ☐ walking
- ☐ Carpooling
- ☐ Other

1.a. If you selected Other, please specify:

2. How do you usually travel (move) between the cities or long distances?

- ☐ Private Car
- ☐ Taxi
- ☐ Coach
- ☐ Train
- ☐ Carpooling
- ☐ Other

2.a. If you selected Other, please specify:

3. What is the type of the Car you are using, or you prefer to use?

Figure (1) illustrating with pictures what is meant by type of cars.

Note: The pictures illustrated do not present the manufacturers but only to explain cars types.

- Hatchback
- Saloon
- Multi-purpose vehicle (MPV)
- sports utility vehicle (SUV)
- Crossover
- Coupe
- Convertible
- Other

3.a. If you selected Other, please specify:

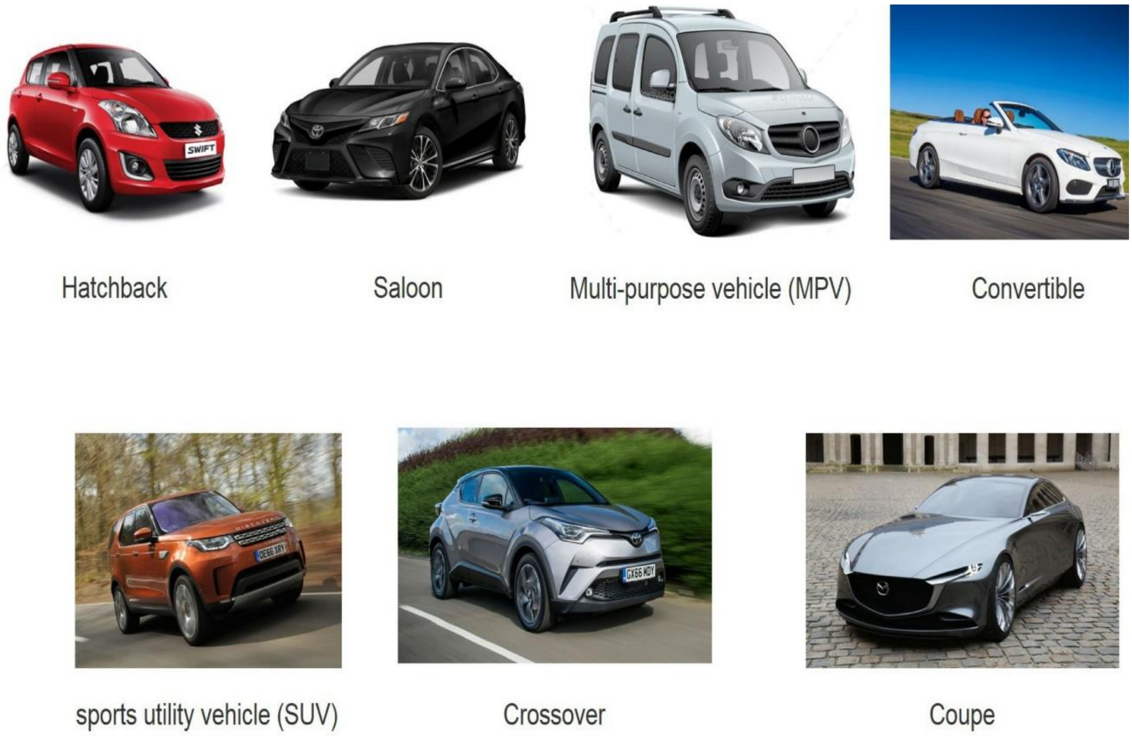

Figure 1. Type of cars

4. Have you ever heard of Autonomous / driver-less or automated cars before taking part in this survey?

- ○ Yes
- ○ No
- ○ Not Sure
- ○ Other

4.a. If you selected Other, please specify:

5. What is your thought about Autonomous Vehicles? Please see the below definition if you have never heard of Autonomous vehicles.

Autonomous vehicle: " is a vehicle that can drive itself without any human assistance. This type of modern technology is achieved employing computer systems and various sensors where the driver is not required. Autonomous vehicles act and make a correct driving decision by sensing and detecting the surrounding environment."

- Extremely positive
- Moderately positive
- Slightly positive
- Neutral
- Slightly Negative
- Moderately Negative
- Extremely Negative
- Other

5.a. If you selected Other, please specify:

6. Would you like to own or share an Autonomous car?

- Own
- share
- Neither
- Other

6.a. If you selected Other, please specify:

7. You would like to use an Autonomous car because of...?
Please, Choose no more than three options

- Safety and reduce crashes
- New service
- Reduce driver stress
- Effectiveness
- Sustainability

- Ideas for sharing
- Reduce congestion
- Efficient Parking
- Independent mobility
- Great opportunities for Deliveries
- Other

7.a. If you selected Other, please specify:

8. Cars will be exposed and collecting a lot of information, Would you keen to share your data? **Note:** This data can be used for health care, insurance, council services.etc.

- Moderately agree
- Slightly agree
- Neither agree nor disagree
- Slightly disagree
- Moderately disagree
- Extremely disagree

9. What kind of data are you willing to share?

- Location
- Hours of use
- Number of people using it with you
- Origin and destination of the trip
- Images/Videos from the Car
- Bio-metrics data
- Other

9.a. If you selected Other, please specify:

10. Even though their high safety promises, Who do you think is to blame in case of an accident?

- Manufacturers
- City Planners
- Owner
- Insurance company
- All the above
- Other

10.a. If you selected Other, please specify:

11. How are you concerned regarding the disappearance of Sports Vehicles and the enjoyment of driving when fully adoption of autonomous vehicles?

- Extremely concerned
- Moderately Concerned
- Slightly concerned
- Neutral
- Not at all Concerned

12. In the case of using a fully autonomous vehicle, how would you benefit from the time while you are being driven instead of driving?

- Sleeping
- Reading
- Working
- Meeting
- Watching TV
- Playing Games
- Simply Enjoying the outside views
- Other

12.a. If you selected Other, please specify:

13. What do you think are the barriers to adopting autonomous vehicles?

Please select between 1 and 3 answers.

- ☐ Cities are not ready (No infrastructures)
- ☐ The cost will be very high
- ☐ Using both modes Manual and autonomous at the same time is not safe
- ☐ People will not accept Autonomous vehicles
- ☐ Ownership identity (Who is going to own Autonomous vehicles)
- ☐ Insurance issues (who is responsible)
- ☐ Other

13.a. If you selected Other, please specify:

Section 2: Participant information

14. Which of the following categories best describe your age?

- Under 21
- 21-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 Or Older

15. What is your Gender?

- Female
- Male
- Others

16. What is your occupation?

- Student
- Employee
- Self-employed
- Retired
- Unable to work
- Other

16.a. If you selected Other, please specify:

17. How long is your home far from your work or study place?

- 0-1 miles
- 1-3 miles

- 3-5 miles
- 5-10 miles
- 10-25 miles
- over 50 miles

18. what is your marital status?

- Single
- Married
- Divorced
- Other

19. what is your level of education?

- High School
- College
- Bachelor
- Masters/PhD
- Other

19.a. If you selected Other, please specify:

20. Further information

City/Town	
Country	
Email Address	

21. Please, you can use this comment box for any comments or suggestions you would like to add.