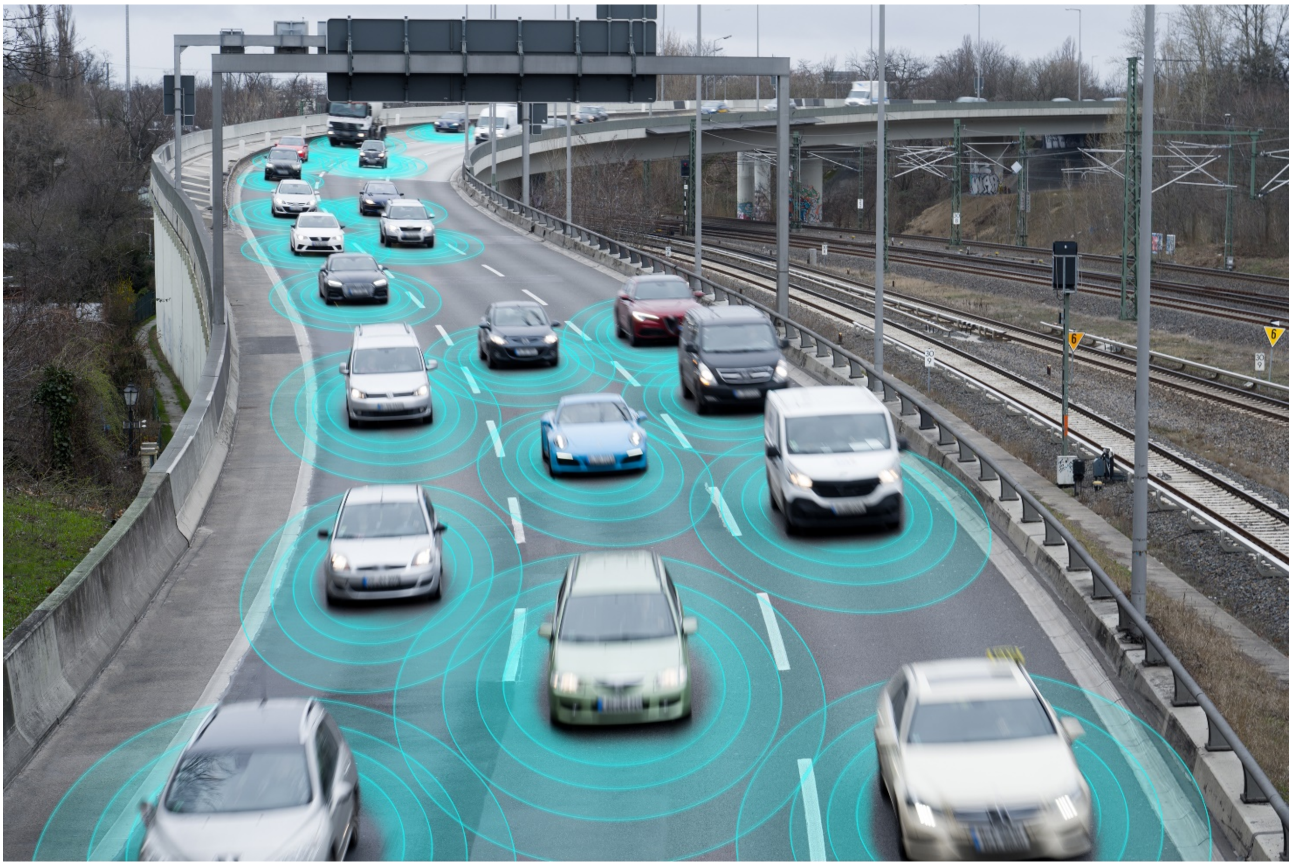
Future of Transport: User Study



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Executive summary

Introduction

- The primary aim of this study was to identify consumer characteristics, barriers and motivations associated with the uptake of different new and emerging transport technologies in the UK. Consumer characteristics in scope of the study included demographic characteristics, attitudes and intentions to use new types of transport, typical travel behaviour and geographical location.
- Three further aims were: 1) to explore the effectiveness of incentives to encourage use; 2) to explore the impact of new transport technologies on public transport and road use; 3) to identify evidence gaps and areas of further development.
- The approach combined a rapid evidence assessment of relevant literature (33 references in total) with in-depth interviews with 15 stakeholders (academics and transport experts). The 33 references, covering both quantitative and qualitative data, were found to be sufficiently robust to be included and most relevant to the research questions. All the reviewed literature was published after 2010 and only covered the UK.
- The study covered the following transport modes: Mobility as a Service, automated vehicles, shared transport, app-based minicab services, demand responsive transport, electric vehicles and electric bikes.
- This study took place before the COVID-19 crisis. While most findings are unlikely to have been affected, some consumer motivations may have changed as a result of COVID-19 (e.g. people may be less willing to use shared forms of transport like ride-sharing).

Key findings

Mobility as a Service (MaaS)

- The Future of Mobility Urban Strategy (2019) defines MaaS as ‘the integration of various modes of transport along with information and payment functions into a single mobility service’. MaaS services were not widely available in the UK at the time of the review. The available evidence was based on user attitudes to hypothetical scenarios and on evidence from small trials within individual cities.
- Typically, MaaS users were characterised as young professionals, living and working in an urban environment and less attached to vehicle ownership than other groups. Likelihood of MaaS uptake among survey respondents in England has been found to be higher for men (43% vs women 29%), younger adults (57% aged 16 to 24 vs 9% aged 65+), people living in urban areas (33% vs 28% rural) and Uber users (60% vs 27% non-Uber users).
- MaaS was seen as a convenient service. The perceived advantages of an app that enabled access to and payment for a range of transport options were making travel and journey planning easier (23% and 18% of respondents respectively) - and lower cost (18%), compared to not having access to such an app.
- Conversely, the perceived disadvantages were higher cost (15%) and a range of digital barriers: over-reliance on a smartphone app (8%), internet access and battery (8%).

- Availability was an important barrier to uptake, with MaaS more likely to be available in areas with good public transport networks and digital infrastructure.
- Digital exclusion was an important barrier for groups with lower smartphone use, e.g. older adults aged 65 and over.
- The evidence indicated that MaaS has the potential to reduce personal car use and increase active travel. A study found that almost a quarter (23%) of survey respondents in England said they would reduce personal car/van use if MaaS were available, and 7% said they would give up their car (although these figures do not necessarily give us an indication of actual behaviour).
- MaaS trial participants in Greater Manchester reported fewer private car journeys and an increase in active travel (walking and cycling), and around 1 in 4 trial participants decided to try new travel modes in response to tailored recommendations made by the app.

Automated vehicles (AVs)

- Automated vehicles are vehicles equipped with advanced driver assistance systems or features that can perform some or all aspects of the dynamic driving task, with partial or no intervention from the human driver. We use the term ‘AV’ throughout this review.
- Potential early adopters of AVs are likely to be men, people on high incomes, young to middle aged individuals and people living in urban areas.
- Technology enthusiasts would be more likely to use an AV, and people who enjoyed driving would be less likely to use an AV than those who did not enjoy driving.
- Consumer types most likely to use AVs for individual trips were ‘Car Dependents’ and ‘Progressive Metropolites’. ‘Car Dependents’ were found to drive a lot, without enjoying driving. ‘Progressive Metropolites’ lived in large urban centres, were highly tech-savvy and had a strong digital affinity. Over half of those belonging to both segments could imagine giving up their car if better alternatives were available. AVs could also be beneficial for those unable to drive for various reasons (e.g. because they are elderly or have a disability).
- Perceived advantages of AVs by survey respondents in England were: enhanced safety (20%); convenience and being able to do other things while travelling (12%); and the ability of AVs to provide travel for older people and people with disabilities (9%).
- In the same survey, safety was raised as the main barrier to general use: potential AV users were concerned about safety of AV technology (45%) and AV safety in unexpected situations (33%) or when interacting with other drivers (27%) or pedestrians (23%). Potential users were also concerned about how well AVs would work in rural areas with poor digital infrastructure and where roads are likely to be narrow or in poor condition.
- The impact of AVs on public transport and road use was not clear from the available evidence. If AVs were widespread, experts considered that they could have the potential to reduce congestion and the rate of traffic accidents by allowing connected and co-ordinated car travel, although it is not clear whether AVs are seen privately or shared public vehicles. However, congestion could increase, particularly in urban areas, if AVs provided a more convenient and low-cost mode of transport than public transport.

Shared services

- This study reviewed evidence about a range of shared services: ride pooling, bike sharing and car sharing.
- User characteristics, barriers and motivations were found to vary across transport type and service, but common user characteristics included: being young or middle aged, well-educated and having a lower than average disposable income, e.g. students, and those living in an urban centre. Users also tended to hold pro-environmental beliefs, have high levels of social trust and openness to new experiences and value convenience and cost saving.
- **Ride pooling** was defined as a taxi you would share with people you don’t know (e.g. Uber Pool). Lower travel costs were the main motivation for ride pooling (67% of people in England), but personal safety/travelling with strangers was brought up as a key barrier to using ride pooling services (42% of people in England). A substantial cost saving would encourage more widespread use of ride-pooling – an Uber Pool for less than £12 (compared with £20 for the regular taxi for Uber) would encourage just under half of respondents to switch to an Uber Pool.
- **Bike sharing** schemes make bikes available for multiple users and include Public Bike Share schemes on the streets or at docking stations, work-based schemes and peer to peer sharing. Bike sharing was most commonly used for door-to-door commuting and last mile journeys. Saving money was found to be a motivator, particularly among those on lower incomes. Barriers to bike sharing included safety concerns, the need to use a bike helmet, difficulty in registering to use the shared bike service, distance to the shared bike station and the availability of bikes.
- **Car sharing services or car clubs** (e.g. ZipCar or Drivenow) were more commonly used for leisure purposes than bike sharing and were typically accessed at off-peak periods. These services motivated consumers by providing a high degree of independence without the cost and responsibilities of car ownership. Barriers to use were concerns about being held responsible for damage by other people and time and parking restrictions for vehicle return (although this was not an issue mentioned in relation to free floating car sharing schemes). A guaranteed parking place on arrival was found to be a strong incentive to increase uptake.
- Lack of awareness and lack of knowledge was a barrier to using shared services in general.

Demand responsive transport (DRT)

- For this research, demand responsive transport was defined as shared passenger transport characterised by flexible routes and small vehicles (e.g. small buses, vans, taxis) that travel between pick-up and drop-off locations according to passengers’ needs. Most of the reviewed evidence focused on more traditional “dial-a-ride” forms of DRT which provide services for specific groups.
- Older people (65 and over) and people with disabilities were more likely to use DRT, as were people in less densely populated areas and areas with higher deprivation and associated lower car ownership rates. These consumer characteristics reflected the original nature of DRT services, promoted as an alternative to fixed public transport services in less densely populated areas where people have few transport options, particularly if they do not have access to a car (‘dial-a-ride’ services).

- Key motivations for using DRT were being able to overcome some concerns normally associated with car use (such as congestion and parking) and offering more flexibility than fixed routes and scheduled services.
- Barriers to using DRT were a lack of awareness and lack of information on the eligibility criteria to access these services, as well as the perception (and related stigma) that these services were purely targeting older people or people with disabilities.
- From the available evidence, it is unclear whether increased DRT offers would reduce private vehicle use, or simply take passengers from other forms of public transport. In rural areas, DRT could provide an alternative to traditional taxi services. In urban areas, greater choice of existing transport modes might lessen the appeal of DRT.

App-based minicab services

- App-based minicab services are platforms that allow users to book rides from a professional driver, with many now offering individual use and pooled use journeys.
- According to a survey in England, users were more likely to be young (aged 16 to 24), men, living in urban areas, highly educated and with a high income. App-based minicabs were primarily used for short journeys (17 minutes on average) and for social or leisure purposes (63%).
- Motivations to use such services included low and predictable costs, convenience, and traffic restrictions preventing personal car use. Barriers to using app-based minicab services included not owning or being able to use a smartphone or credit card, more of an issue for those aged 75+. People with mobility impairments may also be excluded from this market as accessibility requirements of these vehicles are less regulated than traditional taxi services.
- A third (36%) of survey respondents in England said that they had used an app-based minicab to replace a public transport journey, which suggests that these services may already be causing increased congestion.

Electric Vehicles (EVs)

- In this study electric vehicles (EVs) were defined as vehicles that can take on power from an external source and comprise Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs). Hybrid Electric Vehicles were out of scope.
- EV owners were more likely to be male, in the middle-aged group, technophiles, with higher educational qualifications and a high income. They were also more likely to live in a household with two or more cars, where EVs were used for shorter day-to-day journeys and Internal Combustion Engine (ICE) cars for longer journeys or motorway travel. Those who owned or were considering EVs were also more likely to have pro-environmental attitudes and a love of technology. Likelihood of purchasing an EV varied by EV type and whether it was a main or second car: people were less likely to consider buying a BEV (8%) as a main car than a PHEV (20%), although both BEVs and PHEVs held similar appeal as a second car (20%).
- Perceived advantages of EVs among survey respondents in England, regardless of whether they owned an EV or not, were environmental benefits (67%) and lower running costs (32%). Lower running costs was the key reason for buying an EV when asking a sample of EV owners, followed by the belief that EVs are better for the environment.

- Perceived disadvantages of EVs among survey respondents in England included concerns about recharging (56%), concerns about battery (40%) and cost (29%). Likelihood of buying an EV increased as all electric range increased, and as charging time became shorter. Shorter range and longer charge times were more acceptable for PHEVs.
- Research found that trying out an EV over a four-day period increased willingness to purchase a PHEV as a main car (from 6% to 23%) or second car (from 7% to 21%). In terms of willingness to purchase a BEV, the opportunity to try the vehicle increased willingness to consider a BEV as a main car on a much smaller scale (from 3% to 8%), and as a second car (from 7% to 20%).

Electric bikes

- An electric bike is one that is assisted by an electric motor when the rider pedals.
- The evidence focused on *shared* electric bikes rather than personally owned electric bikes. Shared e-bike users included men and women of all ages, predominantly 25 to 65; adults with health or fitness barriers to conventional cycling; and people who rarely or never cycle. E-bikes also provided an important means of transport for those with low incomes and enabled shift workers to travel to and from work where public transport did not fit with their working hours. Half of those who joined shared e-bike schemes (2,667 users across 11 locations in England and Wales) used shared e-bikes at least once a week. In the same programme, it was found that the average trip length on an e-bike was 5 miles (compared with an average journey on standard bikes of 3 miles).
- Barriers to use mentioned in the literature included the cost of buying an e-bike, the challenge of maintenance and repair and the real or perceived effort of cycling.
- Trying out an e-bike was found to drive consideration to buy an e-bike: 29% of all shared e-bike users who completed a follow-up survey said they would be more likely to buy an e-bike after using one. E-bike users were motivated by health, enjoyment, relatively low cost and by the social aspect of using and sharing their e-cycling data.
- There was some evidence that shared e-bikes encouraged mode shift, with 46% of all shared e-bike scheme participants using their e-bike for a journey they had previously made by car as a driver, passenger or in a taxi.

Evidence gaps

Some of the transport technologies covered in this study are relatively new or not yet available in the UK and there was limited evidence relating to their uptake in the UK. The study identified evidence gaps and areas of development.

- There is a need for further research to better understand people’s behaviour, values and motivations when choosing whether to use these technologies when they are more widespread in the UK. There would be value in conducting qualitative research to better understand what people want from future transport technologies, what they value about the transport they currently use and how this affects the level of interest in and uptake of future transport technologies.
- The characteristics of current users tend to reflect the early adopters of these new and emerging transport modes and user characteristics vary by transport type. The characteristics, barriers and motivations of later consumers are likely to differ from those of early adopters. Further research is needed to understand consumer characteristics,

motivations and barriers as these transport technologies become more widespread to ensure these technologies meet the needs of the end users.

- Additional research is needed to understand how consumer characteristics differ between transport modes. It is important to understand whether these transport types compete for the same users or appeal to different groups as competing for the same users may reduce the uptake and potential impact of new transport types. Linked to this is a need for research into how to widen the appeal of different transport types.
- Insight into the uptake of technologies that are still emerging, e.g. MaaS and AVs, is often based on hypothetical propositions, asking people what they think they might do based on 'self-imagined' scenarios. Experts suggested 'real world' research is needed to understand what people actually do, as has been tried with MaaS.
- Real-world research could also be used to understand how experiencing a new transport mode influences uptake and the perceived barriers and motivations to using it.
- More research is needed to identify and address barriers to use of these technologies. Some barriers were related to consumer characteristics and attitudes (e.g. age, income, attitudes towards technology), whereas others were related to availability of the technologies, which are more likely to be commercially viable in high-density areas. Linked to this, stakeholders also suggested carrying out more research involving older adults (particularly those aged 75 or over) to better understand their specific barriers and transport needs.
- Experts also highlighted the need to understand how to highlight good practice on providing these transport technologies across the UK in different types of area, e.g. different cities, towns and in rural areas.
- There was a lack of evidence on e-scooters. The Department for Transport is working with Local Authorities and e-scooter operators to deliver e-scooter trials. DfT will contract and manage monitoring and evaluation activities to build evidence on safety, public perceptions and the wider impacts of e-scooters to inform future policy making. More research would be welcome to understand barriers to use and what could encourage uptake.
- It would be helpful to examine international evidence wherever a technology is more prevalent in other countries.

Glossary and definitions

App-based minicab services
App-based minicab services are platforms which allow users to book rides from a professional driver. They allow customers to connect with a driver using a smart phone application, reducing the need for street hailing and providing similar services to traditional taxis, often at a lower cost. Many app-based minicab services offer either “individual-use” (e.g. Uber), so journeys will be taken alone, or with acquaintances, or “pooled-use” where journeys are shared with strangers with multiple pick-up and drop-off points (e.g. Uber Pool).

Automated vehicles (AVs)
Automated vehicles (AVs) are vehicles equipped with advanced driver assistance systems or features, which can perform some or all aspects of the dynamic driving task, with partial or no intervention from the human driver. Fully automated vehicles are sometimes also referred to as driverless, self-driving or robotic vehicles (Nikitas et al, 2017). Some AVs are connected and have the capacity to ‘synchronise in real-time with all the elements and actors of the transport network, including other vehicles and road transport infrastructure’ (Nikitas et al, 2017). The studies covered in this review have different approaches and terms, including Connected and Autonomous vehicles (CAVs), Automated Vehicles (AVs) and Automated Vehicles (AVs). We will use the term Automated Vehicles (AVs) throughout this report.

Driver assistance features
Driver assistance features are considered as a low level of automation supporting the driver on specific tasks. Technology is designed to improve safety and driving experience and includes features such as automated emergency braking, automated parking and traffic jam assist.

Demand responsive transport
The Community Transport Association and Institute for Mechanical Engineers (2017) defines demand responsive transport as ‘a user-oriented form of passenger transport characterised by flexible routes and smaller vehicles operating in shared-ride mode between pick-up and drop-off locations according to passengers’ needs’. According to Wang et al (2014), four elements characterise demand responsive transport: the service is available to the general public; the service is provided by low capacity road vehicles (small buses, vans, taxis); the service responds to changes in demand by altering its route and/or its timeframe; the fare is charged on a per passenger and not per vehicle basis.

Electric bikes (E-bikes)
An electric bike or bicycle is one that is assisted by an electric motor when you pedal. Electric bicycles are fitted with a small battery powered electric motor and a digital display that allows the rider to control the level of motor input, or assistance. The most common form is the electric assist bicycle where the motor assists the rider’s pedalling, but there are electric bikes that do not require pedalling. Evidence reported here relates to electric assist bicycles. There is relatively little information about electric bikes: the information reported here is from small scale trials and shared e-bike schemes.

Electric scooters
Electric scooters are stand-up scooters fitted with a small electric motor that can assist the rider's efforts. Electric scooters are rarely used in the UK as current legislation does not allow electric scooters to be used on public roads or pavements.

Micromobility
Electric bikes, electric pedal assisted bicycles, shared bicycles, electric scooters and other small lightweight vehicles are collectively defined as 'micromobility'. These forms of transport are relatively slow, with speeds up to 15 mph, and are generally used for shorter trips.

Electric vehicles (EVs)
Electric vehicles (EVs) are powered by an electric motor, using a large rechargeable battery for all or part of their power. Most can be recharged by plugging into mains electricity. There are several types:
1) battery electric vehicles (BEVs) which are always powered by battery
2) plug-in hybrid electric vehicles (PHEVs) which combined a plug-in battery with an internal combustion engine, so can use electric as well as petrol or diesel to drive the wheels
3) extended range electric vehicles which have a plug-in battery, electric motor and an internal combustion engine. The electric motor is used to drive the wheels, and the internal combustion engine is used as a generator to charge the battery (https://publications.parliament.uk/pa/cm201719/cmselect/cmbeis/383/383.pdf)
4) fuel cell electric vehicles use a hydrogen fuel cell to run an electric motor (https://en.wikipedia.org/wiki/List_of_fuel_cell_vehicles) and include hybrid forms.
Emission levels of EVs vary and their classification – as 'low', 'ultra-low' or 'zero' emission vehicles - is determined by the level of carbon dioxide in tailpipe emissions, e.g. ultra-low emission vehicles emit less than 75 grams of carbon dioxide per kilometre.

Mobility as a service (MaaS)
There are multiple definitions of Mobility as a Service. The Department for Transport defines MaaS as 'the integration of various modes of transport along with information and payment functions into a single mobility service' (Department for Transport, 2019b). There are a growing number of MaaS trials in the UK. CityMapper Pass provides an example of subscription based MaaS that allows users to purchase a monthly subscription package giving them access to public transport and private taxi and bike hire schemes. MaaS platforms bring together offerings of multiple service providers and generally offer 'an intermodal journey planner' (Nikitas et al, 2017), which combines different transport modes (bus, underground, rail, car-sharing, car rental, taxi, etc.) and allows for seamless planning, booking and payment for mobility through a digital interface (MaaSLab in Matyas and Kamargianni, 2018).

Shared services
Shared services refer to transport services and resources that are shared among users, either concurrently or one after another (Department for Transport, 2019b). Some examples of shared services are ride-sharing, ride pooling, car sharing or car clubs and bike sharing. Ride sharing, eg LiftShare, is a mode of transport in which an app or website is used to search for others who are willing to share a journey, with one of the users driving. Ride pooling, e.g. Uber Pool is a taxi service booked via an app, that allows more service users to share a journey. In this case, none of the service users drive the vehicle. Car clubs, e.g. ZipCar, use electronic systems to provide customers

unattended access to cars for short-term rental, often by the hour; these are sometimes known as car sharing (Department for Transport, 2019b). Bike sharing schemes, eg Santander cycles, make bikes available for multiple users and include Public Bike Share schemes on the streets or at docking stations, work-based schemes and peer to peer sharing.

Barriers
Existing factors that make people less likely to use a type of transport, including functional, symbolic and social factors.

Motivations
Existing factors or reasons that make people more likely to use a type of transport, including functional, symbolic and social factors.

Incentives
We define incentives as interventions that are deliberately introduced to increase the uptake of particular types of transport. Incentives can be financial, e.g. plug in car grants, or non-financial, or a guaranteed parking space for an EV.

Impact
In this report, we focus on the impact of different types of transport on current patterns of transport use, including public transport and private transport. Other forms of impact, such as health benefits, are out of scope.

1 Background

The focus of this study is the uptake of new and emerging transport technologies in the UK, specifically transport used for personal mobility. The study aims to identify the characteristics of people that are most likely to use these forms of transport, the motivations and barriers to their use, incentives used and the impact of these new forms of transport on current public transport and road use.

Please note that this study reflects transport uptake before the COVID-19 crisis. Motivations and barriers to using different forms of transport may change as a result of COVID-19, e.g. people may be less willing to use shared forms of transport like ride-sharing and more motivated to use electric scooters or electric bicycles.

1.1 Why this study is needed

This study is needed to better understand uptake of new transport technologies in the UK. Our approach combines a rapid evidence assessment and stakeholder interviews to allow us to map out the existing literature and ongoing research. The available information will be used to develop an understanding of which segments of society are most likely to use new transport technologies, and to develop personas around transport use. It is intended that findings will underpin forecasting and policy development around new transport technologies.

The study covers a diverse range of new and emerging technologies that are likely to appeal to different types of users, and to have different motivations and barriers to use. For some there is relatively little UK based evidence to develop consumer personas. We have therefore developed transport 'personas' that describe the users, motivations and barriers for each transport type, the incentives and impact, the evidence gaps and areas of further development. Collating the information in this way provides a useful starting point for modelling technology uptake and for identifying consumer characteristics associated with different types of transport.

1.2 Modelling technology uptake

Information about user characteristics, motivations and barriers is needed to model the uptake of transport technologies. The Technology Acceptance Model (TAM, Davis, 1989), for example, highlights perceived usefulness and perceived ease of use as the key factors associated with current and future use of information technology. More recent adaptations have added social norms, behavioural intention and cognitive factors to allow TAM to be applied in the wider context. Studies of TAM in the context of transport have also indicated demographic and behavioural factors that influence technology uptake. Some examples of this include: intention to use, age and driving experience were associated with acceptance of driverless car technology (Koul and Eydgahi, 2018); attitude towards route diversion was associated with intention to use variable message signs, while familiarity with the network and quality of information were associated with a more positive attitude towards route diversion (Diop, Zhao and Van Duy, 2019).

1.3 Transport segmentation

Segmentation is an approach that divides consumers into groups, or ‘segments’, based on common characteristics, including demographic characteristics, attitudes, behaviours, motivations and barriers. Understanding which segments of society are most, and least, likely to adopt new and emerging transport technologies forms a useful basis for policy development, particularly as different segments are likely to have different motivations and barriers to uptake. A recent study of the market for electric vehicles has highlighted the importance of tailoring policy interventions to different consumer segments as likely to be more effective than a single market wide approach (Morton et al, 2016).

2 Scope of study and research questions

2.1 Scope of study

The primary aim of this study is to identify consumer characteristics associated with uptake of new and emerging transport technologies. Salient consumer characteristics include demographic characteristics, attitudes and intentions to use new types of transport, travel related behaviours, geographical location, as well as motivations and barriers to uptake. The available information will be used to develop an understanding of which segments of society are most likely to use new transport technologies, and to develop personas around transport use. It is intended that findings will underpin forecasting and policy development around new transport technologies.

A further aim of this research is to identify evidence gaps in the existing literature and ongoing research to identify areas where further research is needed.

2.2 Transport technologies

The study covers the transport technologies listed below. Definitions for transport types are included in the glossary:

- Mobility as a Service (MaaS)
- Connected and Autonomous vehicles (AVs); including advanced driver assistance systems or features
- Shared services, internet-arranged or app based, eg ride-sharing, car sharing
- Demand responsive, flexible transport services, internet-arranged or app based
- App-based minicab services
- Electric vehicles (EVs)
- Electric bikes and electric scooters.

2.3 Research questions

The research questions guiding this study fall into three categories: user characteristics, incentives and impact, and evidence gaps.

2.3.1 User characteristics:

1. What are the characteristics of people who use new and emerging transport technologies?
2. What are the barriers to use?
3. What are the motivations or enablers?

2.3.2 Incentives and impact:

4. What incentives have been used to encourage uptake?

5. What is the potential impact of these new technologies on traditional modes and business models, including cars and public transport?

2.3.3 Evidence gaps:

1. What are the main gaps in our evidence base about new transport users?
2. To what extent are evidence gaps filled by current or planned projects? What work are academic and transport experts currently doing?
3. Is there any evidence available now, but not yet published, including articles under peer review, grey literature, and conference proceedings? For planned work, when will the evidence be available?
4. What further primary research/secondary analysis could DfT undertake to fill remaining evidence gaps?

3 Methodology

We used a rapid evidence assessment combined with stakeholder interviews to address the research questions.

3.1 Rapid evidence assessment

The rapid evidence review was used to identify and select key references that addressed our research questions, using a systematic approach.

3.1.1 Search strategy, including citation tracking

References for the title and abstract review were identified through citation tracking, a series of online searches and stakeholder interviews.

Citation tracking was used to identify work linked to key references. This involved a title and abstract review of relevant references listed in the bibliography of our key references (backwards citations) and of more recent work that cited the key references (forward citations), identified through a Google search.

We carried out an online search using Google and Google Scholar, through an academic database (EBSCO), and on specific websites. The search was based on clearly defined search strings based on our research questions and the transport types of interest, and we used different search strings for different websites. The search strings are listed in Appendix A. The literature search was carried out between October and December 2019.

3.1.2 Inclusion criteria

Broad criteria were used to help us to identify relevant literature for each of the transport types and research questions, as there was likely to be a lack of evidence for UK uptake for newer technologies (stage 1). A fuller description of inclusion criteria is in Appendix B. Studies were included if they were:

- published in English
- published in peer reviewed journals, or unpublished
- published post 2010, or data gathered post-2010
- studies with data collected in the UK
- studies with a measure of potential or actual uptake of new transport technologies
- studies that use empirical evidence, including case studies.

At the full text review stricter criteria were included. References were selected if they were:

- identified as a priority reference at stage 1
- an evidence review synthesising multiple studies
- had an outcome measure
- covered UK alone, rather than UK and other countries

3.1.3 Screening process

We used the initial title and abstract review to identify references in scope of the study, based on clearly defined inclusion criteria described above. The title and abstract review was carried out alongside the search. Researchers used the study criteria to identify which references were in scope of the study and which were out of scope. Where the search provided a large number of hits, the study covered an agreed number. For Google and Google Scholar searches, where each search term covered a single transport type, we covered the first 100 references for each search term. For EBSCO, the academic database we used a search string that covered multiple transport types and reviewed the first 500 references. References in scope of the study were retained for the next stage.

3.1.4 Full review

References screened in at the title and abstract review were read in full to collect top-level information against a wider range of criteria. This stage used more narrowly defined criteria to identify the most useful references.

3.1.5 Study prioritisation

The project timelines and goals required an efficient review process so, of all of the evidence found by our search, we report only on those found to be most relevant after a systematic prioritisation process. To identify the key references for data extraction, we prioritised the references using the following criteria using information collected at the full text review:

a) Studies most relevant to our research questions, with priority to studies that covered multiple transport types, address multiple research questions or synthesise a wide body of literature (for example, systematic reviews)

b) Studies with more rigorous methods (including systematic reviews, meta-analyses)

c) Studies published most recently. For example, if there are a series of studies covering a similar area or piece of research, we would select the most recent as this should take into account earlier publications.

d) Lower priority was assigned to more established transport technologies – app-based minicab services and electric vehicles.

e) We also gave consumer characteristics, motivations and barriers a higher priority than incentives and impact.

Studies were assigned a score based on the criteria above. Studies with a higher score were more likely to be selected although some references with a lower score were selected to ensure that the selected references covered the research questions and transport types of interest.

Priority was given depending on transport type covered: references covering multiple transport types were given highest priority (1); those covering MaaS, Shared, or Demand responsive transport, Electric scooters, electric bikes, and AVs were given second priority (2); and reference covering electric vehicles and app-based taxis given the lowest priority (3).

We selected 33 of the 78 references for data extraction (Appendix C). A further 45 references, though in scope of the study, were excluded. References in scope, but not prioritised for data extraction and synthesis are listed in Appendix D. The selected references are listed in Appendix C.

3.1.6 Data extraction

We developed a data extraction template that allowed us to map out information from the selected references against the key research questions. Quality and relevance assessment scores were also recorded on the data extraction template (Appendix G) and are included in Appendix H.

3.1.7 Overview of process

Figure 3.1 illustrates the structure and flow of the review, and the number of references at each stage. The number of references included at each stage is detailed below.

The first stage was used to identify relevant references. We searched for relevant literature using citation tracking and searches on Google, Google Scholar, EBSCO and selected websites. We used a simultaneous title and abstract review to identify the most relevant studies, limiting this to the 100 most relevant studies on Google and Google Scholar, 200 in the case of app-based minicabs. For EBSCO we used wider search terms and reviewed up to 500 studies. We identified 408 relevant references following title and abstract review. 87 references were duplicates (identified in more than one source) and therefore removed before full text review.

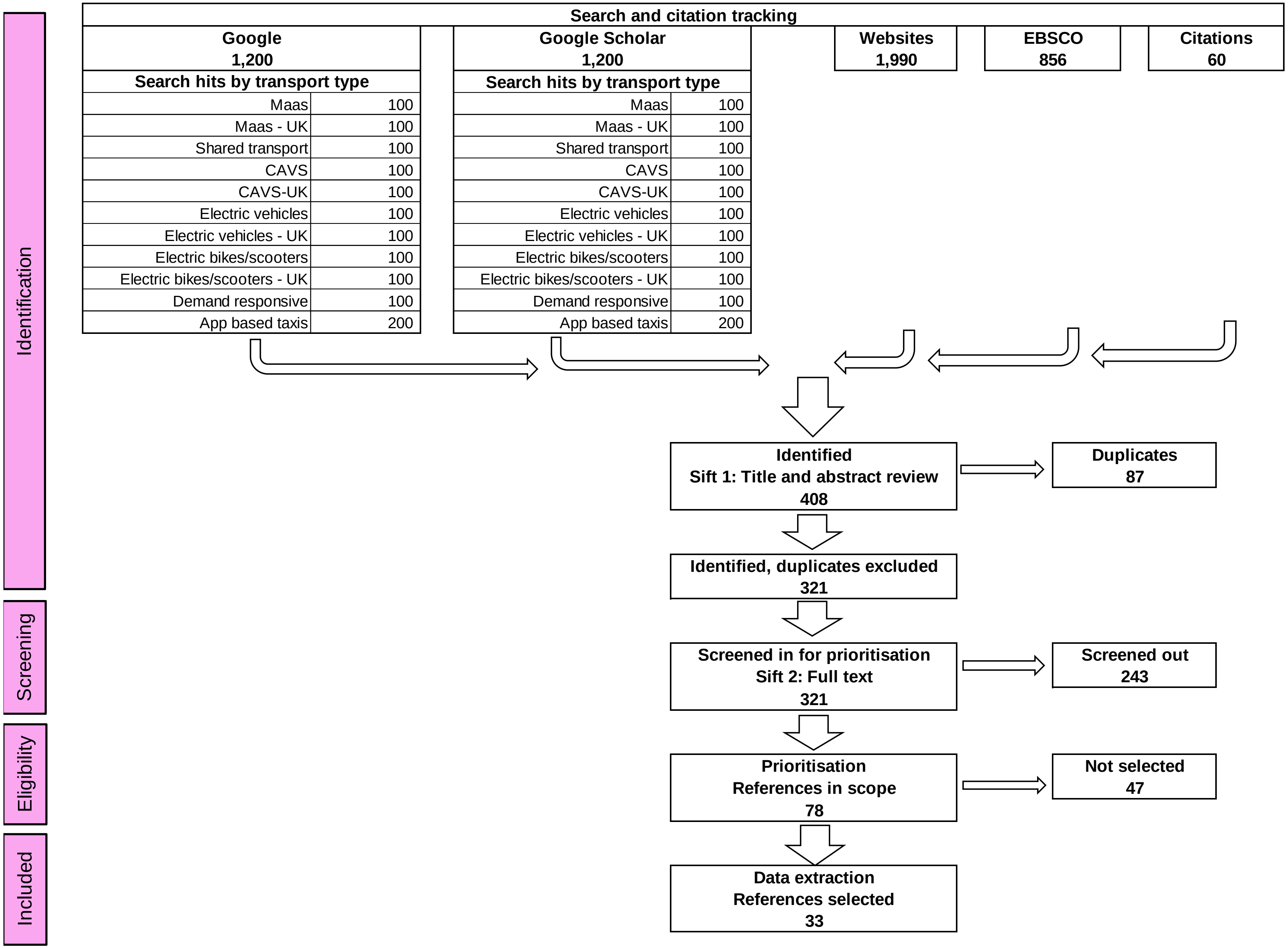
Screening involved a full text review against our inclusion criteria to identify which of the studies were eligible for inclusion. Overall, 321 references were included in the full text review and 243 were screened out as a result of this process.

Study prioritisation was used to identify the eligible studies most useful to the review. The remaining 78 references were in scope for the study and included in the study prioritisation stage. We selected 33 of the 78 references for data extraction based on the criteria set out above, in Section 3.1.5. The 33 selected references included qualitative and quantitative studies, and evidence reviews.

3.1.8 Limitations in the review process

This research project used a rapid evidence assessment methodology to focus on the most relevant evidence. For example, only a proportion of all hits from our search of Google, academic databases and website were screened and inclusion decisions at title and abstract were undertaken by only a single reviewer. This means it is possible that some relevant studies may have been missed. Due to the need for an efficient review process we only synthesised 33 of the 78 studies that met our inclusion criteria. The findings section and review conclusions are therefore based on a proportion of all includable studies and do not provide a comprehensive summary of all relevant evidence, which should be taken into account when considering implications for policy, practice and further research.

Figure 3.1: Number of references selected at each stage of review



3.2 Stakeholder interviews

3.2.1 Purpose and approach

The aim of the stakeholder interviews was to gather information about the existing research around future transport technologies from experts in the field. A total of 15 qualitative interviews were carried out with academics and transport experts from industry, local government and insurance. Interviews explored their knowledge of the evidence, views and perceptions of consumer characteristics and evidence gaps around future transport technologies. Stakeholders were also asked about current unpublished research, and recommended papers and references that they thought would be relevant to the study.

3.2.2 Stakeholder recruitment

Department for Transport (DfT) identified several participants they wished to be interviewed, and others were identified by NatCen in conjunction with the evidence review. Additional stakeholders were identified through a Google search and from key references. Participants were invited via email to take part in the study. As interviews began, respondents were asked for any suggestions of other stakeholders who should be involved in the research, and these contacts were then approached and invited to participate, thus employing the 'snowball' sampling methodology to build the sample.

3.2.3 Interview and topic guide

Interviews took place between October and November 2019, lasting between 30 and 70 minutes, and were carried out by telephone. The interviews were carried out using a topic guide developed in consultation with the Department for Transport (provided in Appendix E), to ensure a degree of consistency while also enabling an informal, flexible approach so that the researcher could respond to the participant's individual areas of interest and knowledge. Key topics included:

- Uptake of transport technologies, including the characteristics of users, motivations and barriers to the use of emerging technologies
- Awareness of incentives available for using any transport technologies
- Awareness of the potential impact of the transport technologies on more traditional modes
- Views on the evidence gaps in research, and existing and forthcoming research or work in this area.

Throughout the recruitment process and at the start of each interview, researchers made clear that the participation was voluntary and explained the level of anonymity and confidentiality of the research. With participants' permission, interviews were audio recorded and transcribed verbatim. The audio recordings were managed and analysed using the Framework approach, whereby data is organised using matrices that enable thematic analysis both within and between cases, allowing descriptive and explanatory analysis to be undertaken (Spencer et al., 2013).

Key findings from the stakeholder interviews are presented in Appendix F. Verbatim quotations are used to provide examples of themes and findings where appropriate. Quotations have not been attributed to protect participants' anonymity. The findings illustrate the range and diversity of views and knowledge of those interviewed. Numbers of participants expressing particular views are not reported as any numerical inference is likely to be misleading or inaccurate because qualitative samples are not designed to be statistically representative of views held in the wider population.

3.3 Synthesis

We used a narrative synthesis approach, structured by transport type and then by research question, to combine findings from the rapid evidence assessment and stakeholder interviews to present a picture of current uptake of transport technologies in the UK. The studies identified in the rapid evidence review were the primary source of evidence used to answer each of the research questions. Evidence from stakeholder interviews was used throughout the report and described separately in Appendix F to illustrate the key themes.

4 Findings

This section describes the characteristics of users and potential users of different transport types, the motivations and barriers to use, and the incentives and impact associated with the different types of transport. Evidence is drawn from the 33 key references selected for data extraction and stakeholder interviews, and findings are structured around the individual transport types and, for each transport type, the research questions set out in Chapter 2.

4.1 Mobility as a Service

4.1.1 User characteristics

In describing the characteristics of users and non-users of MaaS, it should first be noted that there is a relative paucity of evidence regarding the likely uptake of the technology by UK consumer segments, although there may be more evidence internationally. This is due to the fact the technology is still emerging, and as such, examples of MaaS in practice are limited. Thirteen of the studies in the current review mentioned MaaS, although only two focussed specifically on MaaS. The research evidence that has been used to guide this study has therefore been based largely on user attitudes regarding hypothetical scenarios and small MaaS trials within individual cities. It is possible that once the technology becomes more widely available and to larger parts of the population, different patterns of user characteristics may emerge.

Understanding the potential uptake of MaaS is further complicated by the fact that any given MaaS technology may incorporate different elements, such as car sharing or public transport. Each of these components as well as combinations of modes may in turn appeal differently to different segments of society. This section of the report will at first outline the characteristics of users and potential users generally before then considering how such individual components of MaaS may influence uptake.

Despite the relative lack of evidence, a number of key factors and characteristics associated with MaaS uptake have nevertheless emerged. In particular, MaaS users are likely to be younger, well-educated and regular users of multi-modal transport methods within dense, urban areas (Department for Transport, 2019; Government Office for Science, 2019b; Nur, 2019). Accordingly, a key demographic for MaaS is the young professional who lives and/or works in an urban environment. Users may additionally be less attached to vehicle ownership and instead be orientated towards service-based consumption (Kamargianni et al, 2015).

Public attitudes to MaaS were explored in the Transport and Transport Technology public attitudes tracker in December 2018. Around one in three smartphone users said they would be likely to use an app that allowed them to access and pay for a range of transport as well as providing recommendation on the best option based on real time information. Likelihood of uptake was higher among men (43% of men, 29% of women), younger adults (54% of 16 to 24 year olds, decreasing to 9% of those aged 65 and over), BME adults (43% BME, 30% white), those living in urban areas (33% in urban, 28% in rural areas) and Uber users (60% of Uber users versus 27% of non-users).

Regarding geographical area of work or residence, however, the relationship between availability and uptake should be considered as lack of uptake may be associated with lack of available MaaS services and vice versa. That is, while MaaS users are likely to be within-city travellers, this is in part because MaaS requires the availability of multiple transport options and of digital infrastructure to function well. The availability of MaaS and consequently uptake is therefore centred in urban areas. However, this does not necessarily suggest that MaaS does not appeal to those outside of cities. In fact, as the digital infrastructure evolves and expands and as additional modes of transport are introduced outside of cities, uptake may similarly increase within more rural areas.

The digital nature of MaaS services is also associated with user characteristics. Users will be smartphone owners with online access, as it is through these means that MaaS is delivered (Laybourn-Langton, 2017). Individuals without such access are therefore likely to be non-users through a process of digital exclusion. Those most likely to be affected by this are disadvantaged and vulnerable groups, including those on low incomes, older people and other marginalised communities (Nur, 2019).

Uptake of different MaaS components

Matyas and Kamargianni (2018) further explored preferences for MaaS services by the transport types offered within a MaaS service plan and various user characteristics. They used a mixed methods approach involving a survey of around 1,138 respondents to explore current transport use (revealed preference) and preference for different MaaS plans from a range of plans (stated preference). Respondents were presented with a range of scenarios and had to select their preferred plan from four options with different cost and transport options and including fixed and custom plans. Qualitative interviews were then carried out with 30 respondents to explore the reasons for their choices.

The four transport types included in the plans were ‘public transport’ including bus and tube, bikesharing, car-sharing and taxi. Public transport was found to be a core part of respondents’ daily travel habits and was considered an essential aspect of any plan. People over the age of 65 were particularly likely to prefer the inclusion of public transport, while both car owners and non-car owners valued it highly. Without the incorporation of public transport, uptake of MaaS could therefore be expected to be significantly lower than if it were to be included in MaaS services. Despite this, however, respondents with dependent children were less likely than others to select plans with public transport. This survey of 1,138 Londoners found a strong preference across all respondents for public transport to be included within the plan. Evidence selected for this review focussed on London where use of public transport tends to be higher than other parts of the country (Department for Transport, 2018). There is increasing evidence from MaaS trials in other areas, for example, Greater Manchester (SmartCitiesWorld, 2019).

The inclusion of bike and car sharing options was found to be less popular than other options among respondents. However, interest in car sharing aspects of MaaS was found to be greater among those who were already familiar with car sharing services (Matyas and Kamargianni, 2018). As car sharing clubs and users increase in prevalence and availability, this aspect of MaaS may in turn have increasing appeal.

Preference for the inclusion of bike sharing within MaaS services was found to be associated with being under 30 – with those older than 30 being less likely to be users of this MaaS service. It was also found to be more desirable among people that have previously used bike sharing (Matyas and

Kamargianni, 2018). This is not an unexpected finding and shows that users may be initially drawn to MaaS if it incorporates travel modes that they already use (a similar finding was also found for taxi services, car sharing and public transport – as mentioned above).

4.1.2 Motivations and barriers

Motivations

A key advantage of MaaS is its ability to reduce journey times and improve the efficiency of travel. MaaS typically provides a range of interconnected travel options with estimated travel times by various travel modes and takes into account real-time availability so can respond to travel disruption and delays. Users are therefore able to assess and use the fastest and most convenient travel methods for any given journey. However, the variation and potentially unpredictable nature of the best travel options may also act as a deterrent to MaaS for others who are reluctant to move to a different mode of transport or to a multimodal journey.

Findings from the Transport and Technology public attitudes tracker support this view, with respondents, including MaaS service users and non-users, reporting convenience and cost related advantages of using MaaS. The key advantages were that MaaS was seen to make travelling easier (23%), simplify journey planning (18%) and save money (18%). However, some viewed MaaS as more expensive (15%), considered MaaS to be over-reliant on the app (9%) and smartphone battery and internet access (8%). Respondents also mentioned that MaaS might make journey planning (6%) and travel itself (5%) more complicated. It's likely that the perceived benefits and drawbacks of MaaS vary across population groups: those who did not know or report any advantages to MaaS (around 37%) were likely to be older (58% aged 65 and over, vs 41% or less aged under 65), in lower social grades (45% in C2DE versus 30% in ABC1), or have restricted mobility (50% with restricted mobility versus 30% with no mobility restrictions) (Department for Transport, 2019).

While a reduction in journey time is considered a key motivation for the use of different transport methods (Catapult, 2015b), many people nevertheless value the familiarity and predictability of the travel modes that they are accustomed to. MaaS has the potential to remove this familiarity with journeys and may result in journeys becoming more stressful for those who value this sense of familiarity. Given that most journeys are familiar, predictable and take place locally, the option of additional travel choices may seem unnecessary and potentially unappealing. Planning unfamiliar journeys is more likely to be seen as easy if it involves only one form of transport (73% planning car, van or train journeys, and 78% planning a journey by bus or other public transport) than if several different forms of transport are involved (62% considered it easy to plan an unfamiliar journey involving different modes of travel), as MaaS users may have to do (Department for Transport, 2019).

As travel is largely habitual, it is considered important that MaaS should offer the ability to change traveller's behaviour in a staged approach (Nur, 2019). Nur et al (2019) suggest introducing the change gradually, eg by offering additional mobility services to owning a car rather than solely offering transport methods in place of car use, to encourage car owners to start using MaaS. There is the potential for MaaS use to reduce car use as car owners find that MaaS services meet their travel needs (Nur, 2019). Nur (2019) also suggested that, in the early stages at least, MaaS should be seen as complementary to car ownership rather than a replacement.

A further strength of MaaS is its potential to offer convenient solutions to inconvenient aspects of journeys. This may include where an individual is likely to experience delays or has to change between transport modes. Individuals who regularly experience examples of this are especially likely to benefit from MaaS (Community Transport Association and Institute of Mechanical Engineers, 2017).

As various shared service options are included in MaaS plans and services, MaaS is further supported by the rise in shared transport services as the culture of collaborative consumption increases and car ownership declines (particularly among young people) (Enoch, 2018; Kamargianni et al, 2015).

Additional motivations to using MaaS may relate to reducing isolation and improving social inclusion (Nikitas et al, 2017). As with car use, those who are unable to use certain transport modes, have mobility issues or do not travel due to the perceived complexity of travel to certain destinations may find that MaaS has the power to reduce or eliminate these difficulties through increased accessibility to different modes. As a result, users could have greater access to jobs, skills, services and more.

Barriers

An important point to raise here, however, relates to digital exclusion as mentioned previously. While certain groups, such as the elderly or vulnerable and those in low income groups, may have the most to benefit from reduced isolation, these populations may also be dissuaded from MaaS given its reliance on smart phones and lower levels of ownership among these groups (Nur, 2019). In addition to the financial cost and social and habitual norms of smartphone use among these groups, elderly people may also experience the additional issue of reduced finger dexterity that limits their ability to use a smartphone. Therefore, while a rising population of elderly people may indicate a potential increase in the MaaS market - unless alternative, non-digital possibilities of use emerge, this population may in fact be less likely to become users and benefit.

Furthermore, the implementation of MaaS delivery is heavily reliant on the availability of transport and communications infrastructure, as well as a high density of users (Community Transport Association and Institute of Mechanical Engineers, 2017; Nur, 2019). Availability of MaaS may reflect geographical variation in the quality of the digital infrastructure (e.g. network speed) and provision of public transport, with MaaS more likely to be delivered in large, urban areas. The ability to offer real-time information regarding multiple transport types and to incorporate different modes within a centralised system that can be accessed through a single payment method requires a high level of interconnectivity. This is reliant on contractual agreements between transport and MaaS providers, which must include an agreed pricing structure and payment plan (Nur, 2019). Given that the foundations of a successful MaaS business plan are currently largely unknown, this presents a key barrier for MaaS developers.

4.1.3 Incentives

Due to the non-widespread nature of MaaS, there is very little information available regarding incentives for MaaS use. However, a small-scale trial in Greater Manchester (SmartCitiesWorld, 2019; and described in detail in Nur, 2019) developed a MaaS service with a daily personalised travel plan and access to seven modes of transport, single ticketing and real time travel updates and rerouting. The trial involved 39 adults who made 626 journeys over a four-week period, 73% of which were multimodal journeys. Although the sample was relatively small, findings indicated a change in participants attitudes during and after the trial with 21% more willing to use active travel (walking or cycling), 26% of participants were more willing to use public transport and 27% having a more positive perception of public transport.

Forty users were encouraged to try a different mode of travel during the trial, using new travel options that differed from users' preferred options. Around one in four of these different travel options were accepted and such 'nudges' were seen as having the potential to reduce car use by encouraging users to try out different modes. It is worth noting that travel was free during the trial, and that price is an important consideration as MaaS users are likely to be 'price sensitive' (Nur, 2019). Further research is required to determine the effectiveness of possible incentives.

4.1.4 Impact

While the impact of MaaS on traditional modes of transport is largely unknown, a number of potential outcomes are anticipated. Key among these is the reduction in vehicle ownership (Nur, 2019). Although this is predominantly theoretical, as MaaS uptake increases, individuals would become less reliant on car, bike or other vehicle ownership and would instead be able to access shared vehicles or other services as needed. Additionally, with more options available and more information regarding these options, individuals may in turn use a greater variety of transport modes throughout their journeys. This was in fact found to be the case during a MaaS trial in Manchester (Nur, 2019). Those taking part in the trial were found to increase both the amount of public transport they used as well as the amount of active transport (such as walking and cycling) that they engaged in.

The potential impact of MaaS on car/van use was considered in the Department for Transport public attitudes tracker, with respondents who were car owners and smartphone users asked how likely they would be to reduce their car/van use if a MaaS app was available. Overall, 23% said they would be likely to reduce car/van use, with those who were higher social grade, BME or Uber users more likely to say they would reduce car use in response to MaaS. When asked about giving up car ownership, 7% said they would be likely to do so if MaaS was available, and the likelihood of giving up car ownership was higher among those living in urban areas and in London, as well as BME groups and Uber users (Department for Transport, 2019). There is tentative evidence from the MaaS trial in Greater Manchester about the appetite for MaaS and potential impact on car use. A follow up study taking place six months after the trial reported that most of the 39 trial participants wanted to continue using MaaS, and one in three car owning participants wanted to give up their vehicle (SmartCitiesWorld, 2019).

The impact of MaaS on other forms of transport also depends on who develops the MaaS platform. Langbourn-Layton (2017) noted the risk of MaaS platforms increasing the influence of private firms on London's transport system. Although it is not clear from the report what types of private service are referred to, one mechanism is that private MaaS providers may partner with private services (such as private hire cabs), embedding the private services within the MaaS app or equivalent and encourage and promote their uptake among users.

4.1.5 Evidence gaps

There are large gaps in the understanding of how MaaS will work in practice. There is currently little knowledge of what would make a successful business model (Catapult Transport Systems, 2015b) while the understanding of demand and the impact of MaaS on travel behaviour is limited (Matyas and Kamargianni, 2018; Nikitas et al, 2017). This is due to the fact that MaaS is currently in its infancy and as such, there are few commercial applications of MaaS (Matyas and Kamargianni, 2018). While there is some evidence of how users engage with MaaS in the UK, this evidence is predominantly drawn from small scale trials rather than long term applications of commercial services. However, while the knowledge base is currently small, it is nevertheless an area of increasing attention and growth.

4.2 Automated vehicles

4.2.1 Consumer characteristics

Different studies have assessed user preferences for Automated Vehicles (AVs) in a number of different ways, with the approach taken resulting in differing estimates of uptake. A key aspect of the approach taken is the timeline of interest. For example, asking potential users how likely they would be to buy or use AVs as soon as they are available for use by the public will give a different estimate of uptake compared to the likelihood of uptake when the technology is further developed and in use. When the use of AVs becomes more established, concerns about safety may be alleviated, trust in the AV technology will likely be greater and infrastructure may have been developed to support AV use on the roads. Furthermore, given that the technology is still being developed, potential users may give responses about their interest in AVs on a hypothetical basis, in a self-imagined scenario where the technology has been developed further or, alternatively, base their responses entirely on the current state of technological advancement. The high purchase cost of AVs also means that fully automated vehicles are likely to be shared vehicles. Where possible, we draw out consumer characteristics, motivations and barriers relating to specific driver assistance features, shared AVs and privately-owned AVs.

The majority of people (83%) were aware of AVs, defined in the survey as fully driverless or self-driving cars, although only around half (53%) knew at least a little about them. Men (64% versus women 42%), those in higher social grades (ABC1 62% versus C2DE 43%) and car owners (59% versus non-car owners 20%) were most likely to claim at least a little knowledge of AVs (Department for Transport, 2019). Appetite for driverless cars was apparent in 2015, with around four in ten (39%) people saying they would consider using driverless cars today (Catapult Transport Systems, 2015b) although it was not specified if these were shared or privately-owned AVs.

Despite the caveats associated with understanding user preference for AVs, clear patterns have emerged in regard to key demographic characteristics and interest in the technology, although it is not clear from the literature whether these are as privately owned or public shared AVs. Research has repeatedly showed that men, people on higher incomes and young to middle aged individuals are more likely to be potential adopters of AV technology (Axsen and Sovacool, 2019; Government Office for Science, 2019b). Additionally, greater interest in AVs has also been seen among people living in cities (Cavoli et al 2017; Clark et al, 2016).

Users of AVS in general would be more likely to be technology enthusiasts and to report greater trust in technology (Cavoli et al, 2017; Government Office for Science, 2019b). Frequent technology users were also found to be less concerned with potential barriers to uptake such as cost (although the study does not specify whether it's cost of use, cost of purchase or both) and giving up control of the vehicle (Government Office for Science, 2019b).

Driver assistance features

Cavoli et al (2017) note that 'there is general agreement in the literature that there will be four or five stages of automation, starting with advance driver assistance systems and finishing fully automated vehicles'. While fully automated vehicles are just emerging, driver assistance features, e.g. adaptive cruise control, collision avoidance systems and anti-lock braking systems, are available and relatively widespread. Public attitudes to existing driver assistance features provide some indication of how consumers will respond to increasing levels of automation.

Around three quarters (76%) of respondents in the public attitudes tracker survey were aware of at least one driver assistance feature, with levels of awareness ranging from 28% for traffic jam assist, to 47% for automatic emergency braking and 66% for automated parking (Department for Transport, 2019). Awareness of all driver assistance features had increased over the last year, by at least 3 percentage points for each. Overall, 21% were not aware of any driver assistance features, with women (28% versus men 15%) and adults aged 65 and older (32% versus 24% of less in other age groups) most likely to lack awareness.

One third (34%) of those with a valid UK driving licence had used a driver assistance feature, most commonly adaptive cruise control (19%) and in car Wi-fi (17%). Other features used by at least 10% of drivers were lane assist (15%), automatic emergency braking (12%) and automated parking (11%). Men were more likely than women to use driver assistance features in general (men 40% versus women 27%) and those aged 25-34 (41%) and 35-44 (40%) had the highest reported usage.

Individual and shared use of AVs

Merge Greenwich (2018b) carried out an online customer survey and face to face focus groups to understand AV uptake. They examined the differences in likelihood of uptake by the timeline of availability, distinguishing between early and later adopters and asked respondents to consider AV services used for individual trips (using an AV service alone) and for shared rides (using an AV service in 'ride pool mode').

Individual use of AVs

In line with existing research, men were found to be more likely than women to want to travel in an AV 'as soon as possible' with 20% of men stating this, compared to 13% of women. However, 20% of women stated that they would travel in an AV 'when it becomes commonplace' compared to 6% of men. Furthermore, under 35s were the most likely to want to use AVs as soon as possible, with 39% of this group saying this, compared to 28% of over 55s. In contrast, 25% of under 35s said they would wait until AVs become commonplace, compared to 38% of over 55s. This research therefore highlights that women and older users are likely to be more cautious in their uptake of AVs, while men and younger people are more likely to be early adopters.

Catapult Transport Systems (2015b) identified a number of UK consumer segments according to their characteristics and travel behaviours. Two of these segments are particularly likely to be AV users:

- *Car Dependents, accounting for around 17% of the UK population and 24% of journeys* - frequent travellers, almost all journeys carried out by private car, a high number of journeys are for work purposes, live in urban areas, are aged 26-65 and are on middle incomes. They drive purely for functional purposes and do not actively enjoy it, however, 80% drive daily. Around 42% would consider an autonomous vehicle and 69% could imagine giving up their car if better alternatives were available. This group is considered likely to adopt AVs.
- *Progressive Metropolites, 14% of UK population and 16% of journeys* – heavy travellers for work and leisure, multimodal transport users (including car and public transport), tech savvy, young professionals (57% aged 35 or under) with high disposable incomes, believers in the sharing economy and high accepters of AVs (two thirds would consider driverless cars). Around 94% are smartphone users and this group are regular users of public transport, but also use a car for almost half (48%) of their journeys). Although car ownership is important, over half of this group could envisage giving up their car if better alternatives were available. This group constitutes 14% of the UK population and is considered a key market for driverless taxis.

A further group of individuals that may particularly benefit from AVs are those that are unable to drive for various reasons, e.g. because they are elderly or have a disability. This group was shown to be interested in AVs (Axsen and Sovacool, 2019; Government Office for Science, 2019b). Therefore, interest in AVs may not exclusively be among younger people as other research has typically suggested. However, Catapult Transport Systems (2015b) found that individuals who are unable to drive for reasons related to disability or older age are also more likely to be on lower incomes. Intelligent mobility options, including publicly owned AVs, would therefore need to be 'affordable and cost-effective' (Catapult Transport Systems, 2015b, p11).

Adopters of AVs are also more likely to already be car-users (Merge Greenwich 2018b, Clark et al 2016). However, while car users may be more likely to adopt AVs, those who actively enjoy driving find the concept of AVs less appealing (Clark et al, 2016; Catapult Transport Systems, 2015b). Such default motorists, defined as 'petrol heads' make up 9% of the UK population and 13% of journeys, are most resistant to giving up their cars.

Shared AVs
Based on their customer survey, Merge Greenwich (2018b) developed five personas to illustrate potential customer behaviour and uptake of AV ride pool based on key demographic characteristics, classing these as 'indicative' as they are based on a relatively small sample:

- *Forward thinking Fred* (27%): male, mid-high income (above £50K), all ages. Highly motivated to use AV ride-sharing and likely to use with all service designs (eg shuttle, non-fixed, taxi-style). Motivated by cost, convenience and sustainability and not having to park.
- *Independent Ian* (15%): male, low-middle income (less than £50K), all ages. Average willingness to use AV ride pool. No particular motivations for using it and concerned about sharing with strangers and increased travel time compared with driving. Open to using ride pool in future for leisure activities.
- *Hopeful Helen* (26%): female, 'more affluent than other female personas' with an income range of £20-70K, under 35. Highly likely to use AV ride-sharing with all journey scenarios. Motivated by cost, convenience and sustainability and not having to park. Some concern about sharing with strangers.

- *Safety Susan* (11%): female, low to middle income (£22K to £50K), over 35. Highly unlikely to use AV ride pool. Concerns about safety of sharing with strangers, with AV technology being new and with increased travel time compared with a personal car. Might use AV ride-sharing in future for commuting or leisure.
- *Neutral Nancy* (20%): female, typically under 45, all incomes (typically £20K to £50K). Unsure about using AV ride-sharing under any journey scenario. Strong concerns about safety of sharing with strangers as well as some concerns over AV being a new technology, although motivated to use AV ride-sharing in the future.

Merge Greenwich (2018b) reported that 28% of survey respondents who used private cars for leisure and 18% for commuting purposes indicated a high likelihood of using AVs as shared services. A small number of taxi users (6%) also said they would be highly likely to switch to using AVs shared with other users (Merge Greenwich, 2018b). Although the majority (85%) of customers were willing to use an AV in the future, less than half (46%) were willing to share an AV with other users once or twice a week, and around a quarter (26%) to share an AV three times a week or more.

In regard to shared use of AVs, Merge Greenwich (2018b) identified a series of potential service scenarios and identified their level of acceptability among potential users. The most acceptable service was an AV ride pooling shuttle service between two fixed locations. The second most accepted option was for an AV service to deliver shopping. Finally, private non-shared journeys (e.g. AV taxis) were considered the third most acceptable option. An AV ride-pooling service without a fixed destination, where the route is determined by the users, was the least popular and associated with the greatest degree of user concern as the undetermined route reduced users' sense of security.

4.2.2 Motivations and barriers

Motivations

Respondents in the public attitudes tracker survey (Department for Transport, 2019) were asked what they thought were the advantages of AVs, fully driverless or self-driving cars. Just over half (52%) could think of at least one advantage, with enhanced safety (20%), not having to worry about driving (13%), convenience (12%), not needing a driving licence (11%) and making it easier for elderly or people with disabilities to travel (9%).

A commonly reported motivation to use AV technology in general is its potential to improve road safety and limit the number of accidents caused by human error (Axsen and Sovacool, 2019; Merge Greenwich 2018b; Government Office for Science, 2019b). Trust in technology was associated with reduced concerns about safety and increased AV acceptability (Axsen and Sovacool, 2019; Government Office for Science, 2019b).

A further key benefit and motivation to use AV technology is the increased amount of free time and ability to multitask while travelling in a driverless car. Not having to focus on driving means the traveller will be able to instead focus on non-driving activities, including work and leisure (Cavoli et al, 2017; Government Office for Science, 2019b). The convenience and ability to do other things while driving was spontaneously mentioned by 12% of respondents in the tracker survey

(Department for Transport, 2019). However, there are also reports that engaging in other activities while travelling in a AV could result in motion sickness issues (Cavoli et al, 2017).

AV technology may also help to reduce social exclusion, isolation and increase accessibility for people who are otherwise unable to drive (Axsen and Sovacool, 2019; Nikitas et al, 2017; Government Office for Science, 2019b). Around one in ten (9%) respondents in the public attitudes tracker survey mentioned that driverless cars would make it easier for elderly or people with disabilities to drive (Department for Transport, 2019). However, cost of use may be a particular barrier for this group (Catapult Transport Systems, 2015b; Enoch, 2015). There was also a concern that social interaction with a driver could be a particularly important aspect of travelling for vulnerable groups that are unable to drive, and AV technology may in fact increase social isolation in this regard (McCool, 2019). Additionally, some felt that the development of AVs will be directed towards the biggest market rather than those that constitute the greatest need, such as those who are mobility impaired and may require wheelchair accessible AVs (McCool, 2019).

Additional perceived benefits to automated vehicles are energy efficiency, as well as more comfortable journeys (Axsen and Sovacool, 2019).

Barriers

Although safety was seen as an advantage by some this is a contested issue with others expressing concern regarding the safety of AVs. Merge Greenwich (2018b) reported that having a car without a driver seems inherently dangerous to some, particularly if combined with concerns about travelling with strangers. Greater concern about safety issues was found to correlate with being more highly educated (Clark et al, 2016).

When asked about to think about disadvantages of AVs, the majority (80%) of survey respondents could think of at least one disadvantage of fully driverless cars (Department for Transport, 2019). The most common concerns were safety of AV technology and systems (45%), and safety in unexpected situations (33%). Respondents also mentioned safety in interacting with other road users: human drivers (27%) and pedestrians and cyclists (23%) (Department for Transport, 2019).

The ability of AV technology to predict human behaviour has been noted as a wider concern. That is, while AVs may create a safer road environment when *all* vehicles on the road are AVs, there is a fear among some potential users that there may in fact be an increased risk of accidents when AVs have to predict human behaviour in non-autonomous vehicles which is by nature, less predictable (Merge Greenwich, 2018b).

McCool (2019) also highlighted concerns relating to the belief that technology is never fool-proof and that failures are inevitable. Furthermore, there is a worry that in situations where a human driver has to take back control from the AV (e.g. when there may be a high risk of an accident), the driver may lack the necessary focus or ability to react quickly that they would have had in a non-AV (McCool, 2019). Loss of driver control (24%) and drivers becoming lazy or failing to pay attention (11%) were raised as concerns by respondents in a general population survey (Department for Transport, 2019).

Ethical issues were also raised, with some feeling uncomfortable with the fact that AVs would have to be programmed to prioritise some lives over others in emergency situations. However, it was reassuring to people that this programming would be decided by humans (McCool, 2019).

Barriers to privately-owned AV uptake include vehicle cost and affordability of purchase (Axsen and Sovacool, 2019; Clark et al, 2016; Enoch, 2015; Government Office for Science, 2019b, McCool, 2019) although AVs are more likely to be introduced as publicly owned individual or shared transport. The Government Office for Science (2019b) reported interest in using AVs halving if additional costs for purchasing an AV were introduced.

There are also concerns about how AVs might function in more rural environments. In situations where road infrastructure may be less developed, with rural roads in poorer condition, potential users felt uncertain about how an AV would navigate the roads, with concerns that safety issues may arise (McCool, 2019). It was also felt that AVs may take an overly cautious route in these situations, eg avoiding narrower roads, which would in turn lead to longer journey times than if there were a human driver (McCool, 2019). Additionally, there was a worry among potential users that reduced internet coverage, satellite and mobile connectivity in more rural areas could affect the functioning of the AV (McCool, 2019).

There is currently a large degree of uncertainty as to who would be legally liable or accountable if a road accident involving a AV were to occur (Axsen and Sovacool, 2019; Clark et al, 2016; Government Office for Science, 2019b; McCool, 2019; Nikitas et al, 2017). Men are more likely than women to report being concerned about liability issues (Clark et al, 2016). Formal legislation and road regulations will have to be developed to appease these concerns (Nikitas et al, 2017). Catapult Transport Systems (2015b) also state that insurance barriers regarding liability will need to be resolved before AVs can be widely introduced to the market.

A further potential barrier to AV uptake is the fear of the unauthorised or invasive access and use of AV system data. This includes the invasive collection of AV data or journey tracking by the government or other bodies (McCool, 2019), as well as the possibility of hacking and even terrorism (Axsen and Sovacool, 2019; Clark et al, 2016; McCool, 2019; Nikitas et al, 2017). Research respondents wanted assurance that the government would take measures to protect any AV networks from these possible threats and would only use data responsibly (McCool, 2019).

For public ride-sharing AVs there are specific barriers associated with ride-sharing rather than AV technology per se. Merge Greenwich (2018b) claimed the largest barrier for potential users to overcome if they are to use ride-sharing AVs is the ride-sharing rather than AV aspect of this technology. For example, there are concerns that sharing a vehicle with strangers could be frightening, particularly if there is not a driver or similar authority figure present in the vehicle. It is also unclear what ‘social rules’ may apply in the novel social situation of AV ride-sharing, e.g. whether people may feel obliged to talk to others or if ignoring each other becomes the norm. The way in which these social norms develop may in turn act as a barrier or motivation according to an individual’s preference.

4.2.3 Incentives

No information regarding incentives for the uptake of AVs was found. This is not an unexpected finding given that the technology is still emerging.

However, Merge Greenwich (2018b) made a number of ‘passenger centric’ recommendations for future AV services including some designed to address barriers to AV ride-sharing, including: wider education about the safety of AV technology and AV ride-sharing; and to design some services to have an authority figure, a ‘steward’ on board.

4.2.4 Impact

The extent to and nature of which AVs will impact traditional modes of transport is largely unclear as the technology is still being developed. However, once AVs become widespread, it is anticipated that they will result in a reduction in the rate of traffic accidents (Angeloudis and Stettler 2019; Nikitas et al, 2017) and road congestion (Angeloudis and Stettler 2019; Government Office for Science, 2019; Nikitas et al, 2017) due to the connected and co-ordinated nature of car travel, although it is not clear whether AVs are seen privately or shared public vehicles. However, if the number of vehicles on the road remains high, congestion may still be an issue in urban areas (Government Office for Science, 2019b).

If AVs become widely available to people that are otherwise unable to drive (e.g. mobility impaired and older people), there may be an increase in the number of vehicles on the road (Angeloudis and Stettler 2019). It is unclear, however, how the rise of AVs may interact with public transport use. One possibility is that AVs will replace existing modes of transport and the demand for public transport consequently reduces (Cavoli et al, 2017; Government Office for Science, 2019b). Alternatively, in a ‘shared mobility’ scenario, car ownership rates could decrease as ownership models shift, and the growth in AVs and AV ride pooling services could in fact grow with and complement public transport (Cavoli et al, 2017).

Workshop discussions also revealed how the growth of AVs may influence people’s behaviour on an individual level. It was felt that less confident drivers would be better able to use motorways and travel at night (McCool, 2019). Some also felt that AVs may make commuting easier, enabling them to live somewhere else (McCool, 2019). However, there is also the concern that millions of driving related jobs could be lost (Nikitas et al, 2017).

4.2.5 Evidence gaps

The Government Office for Science (2019b) stated that there is currently only a limited understanding of how people will use AVs in practice. For example, whether people will choose to use AVs for work, leisure, or any and all journeys; or what will happen to vehicles when they are empty and where they will go. The answers to these questions could have significant implications for individuals’ lifestyles as well as for society. For shared AV services, attitudes to ride-pooling without a driver present must also be considered.

While a large amount of AV accident and crash data currently exists, it is not publicly available. Instead it is mostly held by AV developers. If this data were to become publicly available, it could help alleviate people’s fears about AV safety and build consumer trust if shared appropriately.

Finally, little attention has so far been paid to how AV non-users may be left behind by a transforming transport landscape. As the technology becomes more widespread, it is unlikely that AVs will be wanted and adopted by all. The extent to which these non-adopters and their day-to-day lives will be affected, eg by the majority of road infrastructure being designed for AVs, is at present unknown.

4.3 Shared services

Shared services encompass a range of shared transport, each likely to be associated with different consumer characteristics, motivations and barriers. Where possible, we have separated information for ride-pooling, car sharing and bike sharing to make it easier to understand the factors associated with each of these transport modes. We found relatively little evidence related to bike sharing in this review. Shared transport services are used for a variety of reasons, with different journey purposes associated with different types of shared service – all forms of service are more commonly found in urban environments.

4.3.1 Consumer characteristics

Interest in shared travel services in general has clearly been shown to be associated with the desire to save money, with uptake higher among those who prioritise this (Axsen and Sovacool, 2019) and among people on lower incomes (Axsen and Sovacool, 2019; Government Office for Science, 2019b).

A key characteristic associated with the uptake of shared services in general is age. Users are likely to be younger, with a sharp drop off in uptake seen among those who are older and middle aged (Government Office for Science, 2019b). The reasons for the appeal to younger people are in part ambiguous, with younger people being both less likely to be able to afford to buy and own vehicles, whilst also being less attached to the concept of owning their own car. If use of shared transport is primarily due to attitudes and beliefs to car ownership then use of shared transport may increase over time as this cohort grows older; if young people are using shared transport because they have a lower income, then their shared transport use may decrease as their income increases and they are able to purchase their own car (Government Office for Science, 2019b). A combination of these factors is, however, likely.

In addition to prioritising saving money, shared transport users place higher value on convenience and score highly in both technological innovativeness and openness to new experiences (Axsen and Sovacool, 2019). However, it is possible that these higher scores may be more strongly associated among early adopters only, and that shared services will have a broader appeal once they become more widespread and people become increasingly familiar with the transport mode.

Ride pooling

In 2018, around a quarter (24%) of respondents to the public attitudes tracker survey were aware of internet-arranged or app-based ride pooling 1% of respondents had used a ride pooling service (Department for Transport, 2019). Among those who had used ‘Uber’ in the last 3 months, one fifth (21%) had used Uber Pool before, and 13% had used Uber Pool for their most recent journey. Please note that the tracker survey used the term ‘ride sharing’ but the services covered, eg Uber Pool, are now more commonly defined as ‘ride-pooling’, the term used in this report (see Glossary for details).

Women and older adults appeared less likely to ride-pool. When asked about the cost saving needed to encourage them to switch to a shared ride, 16% of survey respondents said they would never choose to ride-pool. Women (20% versus men 12%) and older adults (22% of those aged 65+ versus 10% of those aged between 16-24) were more likely to say they would never ride-pool. Around 3% said they would choose to ride pool anyway, even if the shared ride cost did not save them money. The study also indicated some geographical differences in uptake with people in the North East (16% compared with 3% or less in other regions) and those living in rural areas (6% versus urban 3%) more likely to choose to ride-pool.

Axsen and Sovacool (2019) noted that ‘ride hailing’ users, including individual and pooled rides, tended to be younger adults with higher levels of education. Those who used ride pooling were more likely to live in a residence in a ‘walkable’ neighbourhood. Ride pooling is common among younger people, particularly students, who have less disposable income to spend on alternative forms of transport. Additionally, being a user of ride pooling is associated with being extroverted, single and agreeable (Axsen and Sovacool, 2019)

Car sharing

Axsen and Sovacool (2019) characterised early adopters and potential mainstream consumers of car sharing and bikesharing as younger and middle aged, having a lower income, and a higher level of education. Car share users were also more likely to have a young child than non-car share users (Axsen and Sovacool, 2019).

Users are also more likely to be highly educated, with university degree holders being over-represented among car clubs (Le Vine and Polak, 2019). Users also report being environmentally conscious (Axsen and Sovacool, 2019), although some evidence has suggested that the image of being environmentally conscious may be of greater importance than the environmental impact of travel mode itself (Government Office for Science, 2019b).

Despite the higher scores in openness to new experiences, car sharing users have also been shown to be have lower scores in ‘risk-loving’ than non-users (Axsen and Sovacool, 2019). While the reasons for this are unclear, the appeal to more risk averse individuals may relate to certain benefits of shared services, such as the lack of responsibilities associated with ownership. Car sharing was also associated with innovativeness.

In contrast to bike sharing and employer encouraged ride-sharing, the use of car clubs for commuting is much less common. These are mostly accessed at off-peak periods – evenings and weekends. As with bike sharing, car sharing is often used as a ‘last-mile’ connection, although car sharing is also more common for leisure related purposes such as visiting friends or relatives (Le Vine and Polak, 2019).

Bike sharing

Users of bike sharing schemes were likely to be younger and middle aged, have a lower income and a high level of education. User of bike sharing schemes are more likely to be male (Axsen and Sovacool, 2019) although the same is not true for car sharing schemes. Shared bikes were most commonly used for door-to-door commuting, or alternatively as a ‘last-mile’ connection.

Based on bikeshare schemes in London, stakeholders described two main types of user: scheme members and casual users. Scheme members – those who paid an annual subscription for unlimited access to the bikeshare scheme – tended to be regular commuters who used shared bikes for door-to-door travel in urban areas, and last mile journeys. These regular users were more likely to be male, and under 45 years. Casual users, including tourists – those who pay on demand – were more likely to use bikes for discretionary trips including leisure, shopping and visiting friends and family. For this group, shared bike use was 'cyclical', with higher use in the spring and summer, than in autumn or winter.

4.3.2 Motivations and barriers

Motivations

Marshall et al (in publication) explored users' motivations for using shared mobility services and the priority given in decision making. The four key considerations were convenience, cost, comfort and safety concerns around sharing with strangers. Having a convenient, low cost form of transport was most important generally, although the importance of different factors varied depending on type of journey, the availability of public transport, and living in a rural or urban location.

Ride pooling

The main advantages of ride pooling, based on response to the public attitudes tracker survey, were that it costs less than travelling alone (67%), is better for the environment (20%), allows social interaction (12%), helps to reduce traffic congestion (11%) and is safer than travelling alone (5%). Cost was the most common motivation, and more likely to be mentioned by men (69% versus women 64%), those in a higher social grade (ABC1 73% versus C2DE 60%) and Uber users (79% versus non-users 64%). However, 11% saw no advantage in ride pooling, particularly older adults and those who were unaware of ride pooling services (Department for Transport, 2019). Axsen and Sovacool (2019) noted that ride-hailing, including ride pooling, is associated with predictable costs.

The opportunity for social interaction in ride pooling compared to other transport types, may be related to its increased use among extroverted individuals (Axsen and Sovacool, 2019). However, the social environment of ride pooling can also deter users who prefer privacy and avoiding social interaction (Axsen and Sovacool, 2019; Merge 2019b). Even among those for whom the social nature of ride pooling is considered appealing, the main motivation for this mode nevertheless remains the financial savings associated with its use.

Ride sharing

Those who had used ride sharing saw this as a good alternative to 'longer distance trains and costly solo driving' (Marshall et al, in publication). Participants in this study also noted that ride sharing, including car pooling, provided a viable transport option for those working very late or early shifts when public transport was not always available. Users also mentioned the convenience and flexibility of ride sharing compared with fixed public transport, eg train travel (Marshall et al, in publication).

Car sharing

The use of shared services offers a number of advantages to the user. Firstly, and perhaps most significantly, is the fact that it allows individuals to use vehicles with a high degree of independence without the cost and responsibilities of ownership. Given that uptake of shared services is particularly common among those on lower incomes (Axsen and Sovacool, 2019; Government Office for Science, 2019b), this is likely to be a key motivation for the user.

Car sharing offers greater convenience and flexibility than short term rental because use of the services is not limited by office hours but rather operates on a self-service, app-enabled basis, so cars can be used for relatively short time periods and car sharing is less costly than car rental per se (Nikitas et a, 2017).

Bike sharing
Motivations for bike sharing include convenience of shared bikes and saving money, particularly among those on lower incomes (Government Office Science, 2019b). Shared bikes can also be used to support multimodal transport connections, including last mile connections (Nikitas et al, 2017).

Barriers

Ride pooling
The perceived disadvantages of ride pooling, reported in the public attitudes tracker survey, were safety concerns around travelling with strangers (42%), not knowing the person they would be sharing with (29%), longer journey times (27%), and lack of privacy (27%). Over two thirds (69%) of people mentioned a stranger related concern and almost one third (30%) mentioned a journey related concern. Women (49% versus men 36%), BME (48% versus white 42%) and those in certain regions (North East 57% and West Midlands 54%, versus 44% of less in other regions) were more likely to have safety concerns about travelling with strangers: it is interesting to note a higher level of safety concerns in the North East, a region with a greater willingness to ride pool (see section 4.3.1).

Even among Uber users, sharing with strangers was the main barrier to using an Uber Pool, mentioned by 17% of Uber users overall, and more commonly noted by those from BME backgrounds (25% versus 14% white people). Other reasons for not using an Uber Pool instead of an Uber were that Uber Pool was not an option for their journey (10%), they were already travelling as a group (7%), there was little cost saving (7%) and the increased journey time (5%) (Department for Transport, 2019). Merat et al (2017) also noted the increased waiting times as a barrier for ride pooling, compared with other transport modes.

Ride sharing
Sharing with strangers was a concern, particular among non users, and included concerns about personal safety as well as safe driving. Unlike ride pooling, ride sharing does not have a driver present to help to alleviate safety concerns. Those who had used ride sharing services were less concerned as they were reassured by the regulations in place, including checks and user feedback systems (Marshall et al, in publication).

Ride sharing was also seen as less viable in rural areas due to the difficulty of finding another service user with a similar route or location (Marshall et al, in publication).

Car sharing
Car ownership is a barrier to car sharing as ownership confers a number of advantages, including greater access and use than a car scheme might provide. However, the benefits of owning a car may be offset by the perceived risk of car ownership such as the responsibility of owning a car and the costs of maintenance and repair (Government Office Science, 2019b).

Individuals may be dissuaded from using shared services for a number of reasons. Non users thought that car clubs would be expensive and complicated (Marshall et al, in publication). The distance from journey starting point (e.g. home) to the vehicle will, inevitably, vary. The further an individual has to travel to reach the vehicle, the less likely they are to want to use the service (Matyas and Kamargianni, 2018; Merat et al, 2017). This is related to the higher level of use in urban environments with a higher density of users and vehicles available.

As with ride pooling, sharing a service with strangers requires a certain level of trust in others. Potential users have reported concerns regarding the trustworthiness of others, including, for example, fear of contamination or being blamed for someone else's damage to the vehicle (Government Office for Science, 2019b; Nikitas et al, 2017). This issue is partially mitigated, however, as car sharing scheme users are registered subscribers who have passed the necessary checks (Nikitas et al, 2017). Furthermore, younger people have reported being less concerned by these concerns, with the belief that audit trails from using the service would protect them from being blamed for others' behaviour.

Although car share users have a degree of independence in how they use the vehicle, a further barrier to uptake is the need, in some schemes, to return the vehicle to a home bay by a certain time (Government Office for Science, 2019b). This is particularly an issue for journeys in which total travel time, time spent at the destination or the exact time at which the vehicle will be needed, may be unknown. However, free floating car sharing schemes offer an advantage in this regard, as the vehicles do not need to be returned to a specific bay. Car sharing is also unlikely to be a cost-effective means of transport for long distance journeys, for which car rentals may be cheaper, and are therefore only likely to be used for shorter, local journeys. However, car share schemes are likely to be expensive for those who use their cars frequently (Government Office Science, 2019b).

Bike sharing
Barriers to bike sharing included safety concerns, the need to use a bike helmet, difficulty in registering to use the shared bike service, distance to the shared bike station and the availability of bikes. Being 'locked in' to driving as a convenient mode of transport was also a barrier, with users becoming reliant on driving due to the surrounding area, transport options and personal motivations and choices (Government Office for Science, 2019b).

4.3.3 Incentives

Ride pooling
Awareness, although not an incentive, is important as people need be aware of a service to use it. There is scope to improve awareness of ride pooling, even among Uber users – in 2018 around 44% of Uber users were not aware of Uber Pool (Department for Transport, 2019).

Department for Transport (2019) explored financial incentives by asking respondents about the cost saving needed for them to switch from a regular taxi to a shared 'Uber Pool' ride. An Uber Pool for less than £12 (compared with £20 for the regular taxi for Uber) would encourage just under half of respondents to switch to an Uber Pool – the response was similar for those who had used Uber recently, and those who had not. Only 13% of Uber users and 10% of non-Uber users would switch to an Uber Pool if it cost more than £12 (against a £20 taxi fare) suggesting that a substantial cost difference is needed to encourage more widespread use of ride pooling. Around 9% of recent Uber users and 16% of those who had not used Uber recently said they would never use an Uber Pool, indicating that even a significant cost saving may not encourage some people to use a pooled ride.

A further incentive is providing more information to users about passenger safety regulations for ride pooling services (Marshall et al, in publication). Axsen and Sovacool (2019) also note the need to develop ‘credible systems for safety ratings and user profiles’ around ride pooling.

Shared transport users suggested that ‘ride sharing meeting stations’ could be created at key locations, and ride pooling options given equal prominence on the apps to private app-based taxis (Marshall et al, in publication).

Ride sharing
Those who had used ride sharing suggested that service users could reassure non users by providing information about the safety regulations in place and that the Government could play more of a role in regulating the safety of ride share services (Marshall et al, in publication).

Car sharing
A number of car sharing schemes offer a guaranteed parking place on arrival. This can be of particular appeal when commuting to a workplace, for example, where parking spaces are limited (Marshall et al, in publication). These parking spaces may also be cheaper and better than alternative parking spaces in the area of arrival. It is for this reason that employers have reported encouraging employee car sharing schemes. Employees have also reported that they find this incentive to be a key reason for using the scheme.

4.3.4 Impact

The impact of shared mobility services as a whole differs for drivers and non drivers (Marshall et al, in publication). Use of shared mobility by drivers may reduce congestion as drivers use their own cars less often and reduce ‘second car ownership’ as some users choose to use shared mobility ‘instead of buying a second car’.

Ride pooling
Users compared ride-pooling services, like UberPool, with using a private taxi or public transport, suggesting that ride-pooling may impact on taxi use and use of public transport (Marshall et al, in publication). This is reflected in findings from the public attitudes tracker survey where Uber services in general were used in place of public transport (36%), a private hire taxi (29%) or black cab (10%): although the findings relate to Uber journeys in general, there is a risk that UberPool journeys will be used in a similar way.

Ride sharing
Marshall et al (in publication) noted that people who use ride-sharing services tended to compare them to using a private car or taking a train, and users noted that sharing a car provided a convenient alternative to longer distance train journeys or driving alone. This suggests that ride-sharing may have an impact on public transport (train) and private car use.

Car sharing
The largest impact expected to arise as a consequence of the rise of shared services is the reduction in vehicle ownership. Le Vine and Polak (2019) have shown, however, that higher income households are less likely to give up their car as a result of joining a car sharing scheme. Car

ownership would therefore be likely to reduce most significantly among those on moderate and lower incomes – who are also the main users of car sharing services.

Transitioning to paying for car use on a ‘per trip’ basis may also lead individuals to rely less on formed habits when selecting their travel mode (Government Office for Science, 2019b). Users may be more likely to consider alternatives, and consequently, increase their use of other modes, such as public transport, in instances where these modes would provide a better choice, e.g. for convenience, journey time or cost reasons.

Car use has also been shown to be more efficient in regard to vehicle occupancy. Being a member of a car club has been found to lead to an increase in the average number of individuals within each shared vehicle per journey (Angeloudis and Stettler 2019; Laybourn-Langton, 2017). Similarly, car club membership is associated with a lower level of overall car use (Angeloudis and Stettler 2019; Government Office for Science, 2019b). In turn, these factors result in a net reduction in the number of vehicles on the road, leading to reduced traffic congestion (Laybourn-Langton, 2017).

There is currently a lack of evidence regarding the impact of car sharing services on travel behaviour among those that do not otherwise have access to a car (Angeloudis and Stettler 2019).

4.3.5 Evidence gaps

There is also a need to understand how willing people will be to use shared services under different scenarios, determining the aspects of car and bike sharing schemes that are most effective in encouraging new users and retaining existing ones (Government Office for Science, 2019b).

Understanding differences between generations is also important. Consumer characteristics suggest that young adults are less attached to ownership and more open to shared transport than older adults. The Government Office for Science (2019b) note that it is important to explore ‘peak car’ over the life stage to see, for example, if young adults are delaying ownership until they have higher income or a family. It would also be useful to understand how attitudes to and use of shared transport change over the life course, perhaps using a longitudinal approach to understand how transport choices and attitudes of the current cohort of young adults changes over the life course as their income levels and family circumstances change.

4.4 Demand responsive services

4.4.1 Consumer characteristics

Many providers of demand responsive transport (DRT) have a specific group of people that they provide the service to, and therefore have strict eligibility criteria, for example, older or people with disabilities who find it difficult to access public transport (Mounce et al, 2018). Existing flat rate subsidies often support DRT providers to offer services that allow users ‘to access essential goods, services and activities (such as local shops, GP surgeries, day care centres)’ (Mounce et al, 2018). Therefore, consumer characteristics are often specific to the service that is the focus of the study. DRT has historically been primarily seen as supporting people who cannot access mainstream services.

A study by Wang et al (2014) analysed DRT provision in Greater Manchester, which at the time offered one of the largest and most diverse range of DRT schemes in the UK. People in areas with lower population density were found to make more DRT trips. This was thought to be because regular bus services tend to be more limited due to low population density, which resulted in higher demand for DRT.

Wang et al’s (2014) model was based on area data and did not show a significant difference between areas with differing gender or age profiles. This is contradictory to other studies based on passenger data that show a higher proportion of users aged over 65. There was lower demand for DRT in areas with a lower proportion of white people suggesting that there may be cultural factors that reduce demand for publicly provided DRT services amongst non-white people (Wang et al 2014). Demand for DRT was seen to be higher in more deprived areas, but this was seen as a proxy for lower car ownership which would result in more demand for public transport options.

Wang et al’s (2015) study analysed survey data from users of DRT services in Lincolnshire, offered to the public as a whole rather than targeted to specific groups of users. The study found the majority of users were females over 60 years old. Men who reached pensionable age also travelled much more frequently by Demand Responsive Transport than men pre-retirement. Analysis of census data in the Lincolnshire area also showed that population density had an impact on DRT use, with users in less densely populated areas making significantly more DRT trips compared to those living in more densely populated areas.

Wang et al (2015) also considered travel frequency on DRT services and found people with disabilities made more frequent trips than people without disabilities. Those who used DRT to travel to and from work were also more likely to make frequent DRT trips than those travelling for other reasons, not surprising as people are generally more likely to have to go to work several times a week than to go shopping or attend a medical appointment.

This highlighted a potential market segment – those in employment – which would allow DRT in the Lincolnshire area to grow beyond the traditional ‘dial-a-ride’ trips which provide bookable door-to-door transport for older people or people with disabilities who find it difficult to access public transport. 29% of DRT journeys in Greater Manchester were for employment related reasons (Wang et al 2014).

4.4.2 Motivations and barriers

Motivations

A report from the Community Transport Association (2017) includes a case study of a commercially viable DRT service set up in Bristol and claims that this was enabled here as there existed a critical mass of potential users, who were willing to switch away from traditional transport modes to DRT. Key motivations for using DRT were being able to overcome some concerns normally associated with car use (such as congestion and parking) and offering more flexibility than fixed routes and scheduled services. Very few commercially viable DRT services currently exist. The Community Transport Association and Institute for Mechanical Engineers (2017) report described how better availability and use of passenger data may now mean that DRT services are more viable and easier to put in place, as passenger data can be used to design and target DRT services. These new DRT services would however, have a potentially different consumer base to traditional DRT services – for example, those who are more technologically able and do not have specific mobility needs.

Other key motivations found in many of the other studies were lack of available traditional transport modes, for example, infrequent bus services. This is most commonly associated with both lower density urban and rural areas. Car ownership could be seen as a barrier to using DRT, as people are more likely to use their own cars if they are able to. Lower car ownership is positively associated with areas of higher deprivation, and therefore a higher demand for DRT (Wang et al 2014, Wang et al 2015).

Those who used DRT services, e.g. 'dial-a-ride' considered these to be 'more reliable, comfortable and accessible than public transport and much friendlier and affordable than private taxis' (Marshall et al, in publication).

Barriers

A report by DfT and Ipsos MORI (Marshall et al, in publication) using qualitative focus groups and interviews to identify the motivations and barriers for using shared transport identified that one of the main barriers to people using more innovative types of DRT was lack of awareness. All but one of the research participants had never heard of the DRT services offered in their areas. With more traditional dial-a-ride services, there was found to be stigma about using them, and a worry that use could be seen as a lack of independence. In reality DRT users reported increased feelings of independence. Lack of information around eligibility may also be a barrier as people were found likely to assume that they were too young, or not in need enough to use the services (Marshall et al, in publication).

4.4.3 Incentives

DfT and Ipsos MORI (Marshall et al, in publication) identified a number of key incentives for people using traditional dial-a-ride services. These included accessibility of the vehicle and availability of staff to help customers access the vehicle, which was particularly important for those with mobility issues. Consumers also reported that dial-a-ride services were convenient; even though the length of journey may be slightly longer than other modes, they were seen as reliable, which was important for people using these services to attend hospital appointments. Costs of using these services were also seen as relatively cheap compared to alternatives.

4.4.4 Impact

DRT services are seen as important in rural areas with a lower population density, low demand for public transport, and limited fixed route public transport services (Mounce et al, 2018; Wang et al, 2015). DRT services provide essential transport for those who do not drive or own a car, particularly older people, those with limited mobility and people on low incomes. The area-based service in Lincolnshire operated flexible routes within a particular area, picking up passengers from fixed locations in towns or villages or, for those with limited mobility, from their homes. Those using DRT to travel to and from work were found use the service more often which suggests that, in rural areas at least, DRT could support work related travel. Wang et al (2015) did not include car ownership in the model but highlighted the importance of considering this in future research.

Mounce et al (2018) model focused on the potential use of DRT services designed to provide subsidised transport to hospital appointments in an area of rural Scotland. In these areas ‘public funds’ were used to pay for taxis to hospitals due to a statutory obligation to provide travel where other transport options did not exist. Over two thirds of the trips with ‘unmet travel options’ which would have become taxi trips, could instead be covered by DRT. The study indicated that developing DRT services to provide a suitable travel option where none existed, could reduce taxi use.

Whilst there is some evidence to show that taxi use could decrease with more DRT services, the impact on private use of cars is less clear. It is speculated that DRT services currently take passengers from other forms of public transport (eg buses) (Community Transport Association and Institute for Mechanical Engineers, 2017). In order to have an impact on reducing private vehicle use, DRT offerings must appeal to those that currently use a private vehicle by providing a flexible, reliable and convenient option, at a perceived lower cost than the cost of vehicle ownership. These types of services could be appealing in urban areas where there are disincentives for using private cars, for example, parking and congestion, and specific charges such as the congestion charging zone in London (Laybourn-Langton, 2017).

4.4.5 Evidence gaps

Most of the evidence discussed focuses on more traditional “dial-a-ride” forms of demand responsive transport which provide services for specific groups. More evidence will be needed on emerging, more innovative forms of DRT and the consumers of these services as they become more common.

Wang et al (2014) highlighted that an individual level study would be needed to see whether an individual’s characteristics such as their ethnicity affect their DRT usage. There are also gaps in the evidence around service areas (the geographical area covered by a particular DRT service) and fare levels.

Wang et al (2015) explored the impact of individual level factors on uptake of DRT services in Lincolnshire, where most areas as classed as ‘predominantly rural’. Propensity to use DRT services was modelled using survey data (e.g. service area, trip frequency, trip purpose, satisfaction and users’ demographic characteristics) and Census data such as population density. Wang et al (2015) suggested that the approach could be developed to assess demand for DRT in non-rural areas, and to understand the impact of additional factors, e.g. household income and car ownership, on propensity to use DRT.

Whilst there exists some evidence to suggest that use of DRT will lead to a reduction in taxi use, there are gaps in the evidence base as to whether demand responsive services would have an impact on private car use, or whether an increase in these services would simply take customers from existing traditional public transport services.

4.5 App-based minicab services

4.5.1 Consumer characteristics

In 2017, there were around 8.35 million ride-sourcing platform users in the UK, and the number was expected to increase to over 11 million by 2020 (Angeloudis and Stettler, 2019).

The Department for Transport's public attitudes tracker provides insight into awareness and use of app-based minicab services, based on a sample of over 3,500 respondents in England in December 2018 (Department for Transport, 2019). There was a high level of awareness: 77% of respondents were aware of app-based minicab services. Although respondents were generally aware of app-based minicabs, just a quarter (28%) of respondents had used an app-based minicab service in the past, 18% within the past 3 months. Users of app-based were more likely to be men (19% men, 16% women), younger (31% 16-24, 20% or less for older age groups), BME (29% BME, 16% white); urban (19% urban, 10% rural), higher social grade (ABC1 23%, C2DE 12%).

General interest in transport innovation tended to be associated with higher incomes, and younger and middle-age groups. However, other studies reported that gender did not appear to have an influence on use of app-based minicab services (Axsen and Sovacool, 2019). As app-based minicab services and ride-sourcing platforms are predicated on the use of both smartphones and credit cards, they are seen to be excluding those without access to either of these, and appealing disproportionately to younger, better educated, higher-income, urban-dwellers (International Transport Forum 2019).

There are also concerns that people with mobility issues, who are often seen as users of traditional taxis, will be excluded from the rise of app-based minicab services as accessibility requirements of these vehicles are less regulated than other forms of taxi service (International Transport Forum 2019).

In terms of geographical characteristics, pooled ride-hailing was associated with living in a walkable neighbourhood (Axsen and Sovacool 2019). The provision of app-based minicab services grew fastest in London and other urban areas (Laybourn-Langton, 2017), although ride-sourcing platforms have seen widespread market adoption wherever they operate (Angeloudis and Stettler, 2019).

Journey characteristics

The public attitudes tracker asked recent app-based minicab users about their journey (Department for Transport, 2019). App based minicabs were primarily used for social or leisure purposes (63%) and also for work (12%), personal business (11%), travel to and from stations and airports (9%), travel to and from shops (5%). Average journey length was 17 minutes, and two thirds of journeys were 20 minutes of less.

4.5.2 Motivations and barriers

Motivations

Motivations for using app-based minicab services include the low and predictable costs of these services compared to other traditional taxi services. Regulation such as the Congestion Charge Zone in London also makes app-based minicab services a viable option over personal car use (Laybourn-Langton, 2017).

Higher levels of use for social and leisure purposes (Department for Transport, 2019) may reflect convenience, e.g. for travelling as a group, as well as greater reliability, e.g. travelling in the evening when public transport is less frequent. Travel to and from shops was reported more often by those in lower social grades (11% C2DE, 1% ABC1) which might suggest a link with car ownership, with app-based minicabs being used to transport heavy shopping.

Barriers

Barriers to using app-based minicab services include not owning or being able to use a smartphone or credit card, so these services are only available to those who have a certain level of technology available to them. Those who do not have smartphone access are more likely to be older (less than one in five aged 75+ personally own a smartphone), to have a disability (53% of people with disabilities have access to a smartphone, compared with 81% of people without disabilities) although this may partly reflect the age profile of this group (Ofcom, 2019). Lack of regulation of vehicles on ride-sourcing platforms can create a barrier for those with mobility issues and other disabilities (International Transport Forum 2019).

4.5.3 Incentives

Incentives for using app-based minicab services included the low and predictable costs of using these services, particularly ride-sourcing platforms (Axsen and Sovacool, 2019). The relatively low and predictable costs of app-based minicab services, and the convenience and flexibility of a private vehicle make these services appealing.

4.5.4 Impact

Evidence from the public attitudes tracker (Department for Transport, 2019) indicates that app-based minicabs were used in place of a private hire taxi (29%) or a black cab (10%), or some form of public transport (36%), most commonly bus (15%) or train (12%), or walking (6%). The impact of using an app-based minicab appeared to be associated with consumer characteristics. Car owners (43% car owners, 30% non-car owners), white people (44% white, 25% BME) and those living in rural locations (56% rural, 37% urban) were more likely to use an app-based minicab instead of a private hire taxi or black cab. Men (41% versus women 31%), non-car owners (55% versus car owners 27%) and BME (48% versus white 32%) were more likely to use an app-based minicab to replace public transport.

The number of Private Hire Vehicles (PHVs) has increased as ride sourcing platforms have emerged. Between 2013 and 2017 the number of private hire vehicles in London (including traditional minicabs, ride sourcing, ride-sharing and car sharing) increased by 39% to 87,400, accompanied by a 50% increase in PHV drivers to 117,700, while the number of taxi drivers has remained stable (Angeloudis and Stettler, 2019). A similar pattern was seen across England and Wales as a whole.

Axsen and Sovacool (2019) cite literature which explores the rebound effects of app-based minicab services. This is where potential for reductions in costs and travel time can lead to an increase in usage that cancels out a portion of the expected societal benefits, such as environmental impact, reduced congestions, improved safety, if, for example, there is a move away from public transport to app-based minicabs. It is suggested that 'widespread use of pooling is essential to ensure that ride-hailing helps to reduce overall vehicle travel (even if passenger travel increases)' (Axsen and Sovacool, 2019, p12). Lower travel costs and travel times have the potential to encourage switching away from public transport and driving longer distances, and to influence where people choose to live (making it easier for people to move further away from urban centres) reducing environmental benefits of app-based minicab services.

There is conflicting evidence on whether an increase in adoption of these services has increased car traffic on the roads or reduced it. In support of reducing car traffic, app-based minicab services can be seen to connect passengers to public transport hubs, provide transport in low density areas and to provide an affordable and efficient alternative to unsustainable transport behaviours, such as over reliance on cars. App based minicabs also have the potential to help to lower air pollution and congestion as well as opening up safe and clean transport coverage to areas of low public transport density (Laybourn-Langton, 2017).

However, app-based minicabs could also increase car traffic, particularly if app-based minicabs are used in place of public transport or active travel as evidence from the public attitudes tracker suggests. Evidence shows that the increase in numbers of private hire vehicles is increasing congestion in central London during the working day as well as during evening and weekend peaks. TfL have identified Uber as one of the key drivers of the increase in private hire vehicle licences over the last 10 years. Conversely, Uber claims that congestion increases are the result of roadworks and the growth of delivery journeys as online commerce increases. The Uber pool services which allow users to car-pool and share journeys is said to have saved 1.3 million miles driven, 98,000 litres of petrol and 231 metric tonnes of CO_2 since 2015 (Laybourn-Langton, 2017).

4.5.5 Evidence gaps

Angeloudis and Stettler (2019) noted that current travel surveys do not differentiate between taxis, traditional private hire vehicles, ride sourcing companies, ride-sharing and car sharing and do not adequately capture new shared modes of travel. Defining these services more clearly in transport surveys, and including other new transport technologies, would give more precise information on the uptake of these services. The authors also note the potential to collect more detailed travel data from a range of sources, such as 'mobile phone movements, vehicle telematics, app use and data from mobility service providers' to get a better understanding of ride sourcing, ride-sharing and car sharing including travel details, location and timing.

There is mixed evidence on the impact of app-based minicab services and, as users reported they would otherwise have used public transport (36%) or walked (6%), their use may lead to increased congestion (Department for Transport, 2019). Wider use of shared cabs has been suggested as a way to offset this risk, as the number of individuals using app-based minicabs increases, however the evidence we have reviewed does not clearly differentiate between shared and individual use. A better understanding of the use of individual and shared app-based minicabs and the transport modes these are replacing would be useful.

4.6 Electric vehicles

In this report electric vehicles (EVs) are defined as vehicles that can take on power from an external source and comprise Battery Electric Vehicles (BEVs) and plug-in Hybrid Electric Vehicles (PHEVs). Hybrid Electric Vehicles are excluded. The Society of Motor Manufacturers most recent figures recorded over 22,000 BEV registrations between May 2019 and May 2020, and a further 14,500 PHEV registrations. Together BEVs and PHEVs accounted for over 7% of the market share of newly registered cars and had increased their share of the market since the previous year (SMMT, 2020).

4.6.1 Consumer characteristics

The majority (92%) of adults were aware of electric vehicles, although there was a relative lack of knowledge with 65% claiming to know at least a little about them (Department for Transport, 2019). Men were more likely than women to claim knowledge of electric vehicles (76% versus women 53%) as were those with a higher social grade (ABC1 74% versus C2DE 55%). Conversely, the oldest age group aged 75 and over were least likely to have knowledge of EVs (46% compared with 56% in younger age groups) and there was some geographical variation with adults in the North West and North East of England less likely to claim knowledge than other regions.

The characteristics described below reflect current electric vehicle owners, those who are considering buying an electric vehicle and drivers who have taken part in EV trials. As with AVs, the context is important, as owner and user characteristics may reflect the type of EV considered, e.g. purely battery or plug-in hybrid, as well as the timeline and how well established EVs are. Electric vehicle owners are not a homogenous group and the characteristics of early buyers are likely to differ from later buyers (Anable et al, 2014). The characteristics of early adopters are similar to those of new car owners: 'generally middle aged, male, well educated, and live in urban areas with households containing two or more cars and with the ability to charge at home' (Brook Lyndhurst, 2015, p.19).

Anable et al (2011) used segmentation analysis to identify consumer personas with different attitudes to BEVs and PHEVs, describing the key features of each group. At the time, those more likely to adopt electric vehicles were:

- Plug in pioneers – young (29% under 34 years, 19% over 65 years), male (56%), with a very high income, high education, likely to have children
- Zealous optimists – older (17% under 34 years, 22% over 65 years), male (61%), high income, mostly employed, lower levels of education
- Willing pragmatists – oldest (13% under 34 years, 27% over 65 years), male (58%), high income, high proportion retired, high education

Consumers least likely to adopt electric vehicles were:

- Image conscious rejectors – female (63%), younger (24% under 34, 18% over 65), average income, most working, lower levels of education

- Conventional sceptics – male (58%), average age range (19% under 34, 25% over 65 years), mostly employed with lower levels of education

However, it is important to note that the characteristics of these personas may have changed given the increasing prevalence and development of electric vehicles.

More recently, Beard et al (2019) carried out trials of BEVs and PHEVs with 200 'mainstream' drivers, excluding those with EV experience, who trialled the vehicles over a four-day period. The sample included three key consumer groups, and findings relate to Plug in Vehicles (PiVs) as a whole, including PHEVs and BEVs:

- Pragmatists (50% of sample): young, low income, generally drive medium size cars, average annual mileage with few long trips, do not link cars to status, not really interested in new technology, very interested in fuel economy, negative attitudes to environment and negative attitudes to PiVs
- Cost conscious greens (26%): young, medium income, generally drive medium sized cars, average annual mileage, frequent long trips, interest in new technology and high interest in fuel economy, environmentally conscious, positive attitudes to PiVs
- Uninterested rejectors (19%): older, lower income, generally drive medium sized cars, low annual mileage, few long trips, do not link cars to status or particularly like cars, low interest in new technologies, negative attitudes to environment and to PiVs

The study explored attitudes to BEV ad PHEVs before and after the vehicle trial; future purchasing decisions and willingness to buy an EV as a main or second car, and differences between consumer segments; and the importance of different vehicle characteristics in purchase decisions. Findings from this study are reported throughout this section to illustrate attitudes to EVs, the perceived motivations and barriers for purchase, and the impact of 'trying out' an EV on likelihood of purchase and attitudes to EVs.

Demographics

On the whole electric vehicle owners and potential adopters were more likely to be male, middle aged, have high income, a high level of education, to be living in a multiple car owning family and to have family or friends with electric vehicles.

Men were generally more likely than women to own an electric vehicle (Anable et al, 2011; Anable et al, 2014; Axsen and Sovacool 2019; Brook Lyndhurst, 2015; Government Office for Science, 2019b), with one UK survey reporting 89% of EV owners as male, 11% female (Hutchins et al, 2013). The gender difference is marked compared with overall vehicle ownership: in 2017, 76% of men and 69% of women in the UK owned a car or another motor vehicle (Statista, 2019). The reasons for this are unclear as men and women seem to have similar motivations to purchase an electric vehicle (Government Office for Science, 2019b) and women have a strong preference for environmentally friendly cars (Anable et al, 2014). However, the survey was carried out in 2013 when EV sales were relatively low (0.16%) and therefore represented an early stage in the EV car market (Brook Lyndhurst, 2015).

The age profile appears mixed with some evidence of electric vehicles appealing to younger males (Axsen and Sovacool, 2019; Anable et al, 2011) and others showing a middle age group. In an early survey around three quarters of EV owners were aged 40-69, with a relatively even spread across the 40-69 age range (23% aged 40-49, 29% aged 50-59, 23% aged 60-69). Anable et al (2011) described a small group of earliest adopters as young, males with a high income, however in general, younger people are considered less likely to buy an EV because of cost barriers (Government Office for Science, 2019b). Other groups identified by Anable et al (2011) - the optimists and pragmatists – had an average age of 55 to 64.

High income was a common factor associated with likelihood of buying an EV, with some evidence of higher income levels among earlier adopters. Based on the adopter categories in Roger's (1962) diffusion of innovation model, a theory describing the uptake of technology over time, Anable et al (2014) reported that 'early adopters' (the second group to adopt) tended to have a higher income than the 'early majority' (the next group to adopt), who in turn had a higher income than the average car buyer. Similarly, the plug- in pioneers, were described as having a very high income (Anable et al, 2011). This pattern of income may reflect the cost of buying an electric vehicle (Hutchins et al, 2013).

Higher education was also a common factor, with Hutchins et al (2013) reporting that 69% of early EV owners had a degree or diploma.

EV owners were also more likely to be family households (Anable et al, 2011; Anable et al 2014). Hutchins et al (2013) reported that 72% of early EV owners in their survey were 'Educated Suburban families'.

Finally, EV owners and considerers were more likely to live in a neighbourhood with EVs, and possibly to have family and friends with electric vehicles, although the latter was not significant when demographic factors were taken into account (Government Office for Science, 2019b).

Beard et al (2019) explored willingness to purchase an EV in the next 5 years, before and after trying out a BEV; being 'very likely' to buy was seen as a predictor of uptake. Before the trial around one fifth (20%) of participants said they would be fairly or very likely to purchase a PHEV as a second car or main car in the next 5 years, or to purchase a BEV as a second car, but willingness to purchase a BEV as a main car was lower (8%). After a four-day trial using a BEV or PHEV, participants views changed. After the trial, participants were more likely to purchase a PHEV as a main car (increased from 6% very likely before the trial to 23% after) or second car (increased from 7% to 21%). However, there was a difference in the shift in attitudes for different consumer groups: while pragmatists were more likely to choose a PHEV as a main or second car after the trial, other segments were less likely to choose a PHEV as a main car and did not change their willingness to choose a PHEV as a second car. The author's note that further research is needed to explore the attitude shifts in different consumer segments. For BEVs, participants were generally less likely to purchase a BEV as a main car after the trial. Trying out a BEV appeared to 'polarise' responses to having a BEV as a main car, with the proportion who were 'very unlikely' to purchase a BEV increasing from 17% to 31% and the proportion who were 'very likely' to purchase, increasing from 3% to 8%. Likelihood of having a BEV as a second car, however, increased ('very likely' increased from 7% before the trial to 20% after) and the increase was apparent in all three consumer segments.

Geographic characteristics

Early adopters were described as mainly urban dwellers. Almost two thirds of EV owners lived in an urban area – 17% in London, 46% in an urban area outside London – while the remaining third lived in a rural area - 18% lived in a town or fringe area, and 11% in a hamlet, village or other area (Hutchins et al, 2013).

Attitudes and beliefs

Those who owned or were considering electric vehicles were also more likely to have certain attitudes or beliefs, including pro-environmental attitudes and a love of technology. Electric vehicles are considered to have private-symbolic ‘value’, acting as a social signal or symbol of pro-environmental attitudes, or an adventurous or innovative person (Axsen and Sovacool 2019).

Those who identified themselves as having ‘pro-environmental’ attitudes had a more positive perception of EVs (Government Office for Science, 2019b). While concern about climate change itself was not a predictor of EV purchase, buying an EV was influenced by the symbolism of EV purchase, demonstrating pro-environmental beliefs or social innovation (Government Office for Science 2019b).

Beard et al (2019) found that those interested in new technology were generally more willing to consider a PHEV as a main car, although they noted that other personal and individual factors were not good predictors of willingness to adopt PHEVs. For BEVs, greater willingness to consider a BEV as a main or second car was associated with having a ‘green’ identity, interest in new technology, and having a careful driving style (Beard et al, 2019).

Behavioural characteristics, including typical travel behaviour
Electric vehicles were more common in households with two or more cars (Anable et al, 2011; Anable et al, 2014; Brook Lyndhurst, 2015). Households with two or more cars were more likely than one car households to say they would adopt a BEV as their main car (Anable et al, 2011). It was also suggested that the earliest adopters were most likely to buy new and larger cars, and to spend more on their cars (Anable et al, 2011).

Brook Lyndhurst (2015) highlighted higher EV uptake in households with two or more cars as well as the ability to charge at home. Higher EV ownership in these groups may reflect higher income, being able to charge at home and also the flexibility offered by having an EV and an ICE car. Hutchins et al (2013, described in Brook Lyndhurst, 2015) reported that 80% of early EV owners had two or more cars, and the majority (97%) had charged their car at home.

EV owners and considerers were more likely to take part in car sharing (Government Office for Science 2019b). For those who take part in car sharing, the availability of electric vehicles in a car share scheme may be an important motivation to EV use. Indeed, fleet owners are important in developing the early EV market (Anable et al, 2014) and also provide an opportunity for potential buyers to try out EVs.

Journey characteristics

One fifth (20%) of EV owners had the EV as their only car. In EV owning households with two or more cars, 18% used the EV as their main car. Those with PHEVs were more likely to have one car (29%) than BEV owners (17%) (Hutchins et al, 2013).

EVs were used for a variety of day to day journeys, including commuting to work, education, doing shopping, visiting friends, ‘typically regular journeys that owners undertake several times a week, over relatively short distances’ (Brook Lyndhurst, 2015, p31). EVs were less likely to be used for longer journeys or motorway travel. Over a quarter (27%) had not used their cars on a motorway, with BEV owners more likely to report this (31% of BEV owners and 19% of PHEV owners had not used their car on a motorway) (Brook Lyndhurst, 2015).

Hutchins and colleagues (2013) found that annual mileage for EVs (around 8,850 miles) was comparable with that for ICE cars (8,430 miles). This might be affected by the type of EV, as high annual mileage, over 12,000 miles, was more likely to be reported by PHEV users (28%) than BEV users (18%, Hutchins et al, 2013). In a more recent study, Beard et al (2019) reported a similar difference in EV trials: during the four-day trial period, mean trip distance for PHEVs (8.6 miles) was significantly longer than that for BEVs (7.4 miles) although both were broadly comparable with that for ICE cars (8.0 miles).

Charging is another important consideration for EV users. The vast majority (95%) of EV owners charged their EVs at home, 26% charged their car at work and 12% used public charging. Most owners charged their cars daily, and typically overnight (Brook Lyndhurst, 2015).

4.6.2 Motivations and barriers

Motivations

Respondents in the transport and technology tracker survey were asked the perceived advantages of EVs (Department for Transport, 2019). The most commonly mentioned were environmental benefits (67%), lower running costs (32%) and EVs being quieter than conventional ICE vehicles (17%). Other advantages were mentioned, but by less than 10% of respondents.

Hutchins et al (2013) conducted a survey of private EV owners which showed the key reasons for buying an electric vehicle were: ‘to save money on fuel, petrol/diesel is expensive’ (58%); ‘electric cars better for environment, greener (42%); ‘Like new technology; electric vehicles new/exciting/fun’ (38%); ‘climate change/global warming/CO2 emissions’ (17%); ‘London congestion charge, no road tax/vehicle excise duty’ (14%); ‘traffic pollution/air quality/traffic pollution bad for people’s health’ (9%); ‘oil dependency, to reduce dependency on oil’ (9%); and the ‘Government plug-in car Grant / electric car Grant / Grant (any mention)’ (5%).

Saving money on fuel costs appeared to be the most common motivation for buying an electric vehicle, particularly when fuel prices are high. Anable (2014) asserts that it is ‘not the cost of oil per se that makes the most difference, but the speed with which prices rise and the relative cost *vis-à-vis* electricity prices’ (Anable et al, 2014, p.95). However, users tended to omit the cost of electricity from their fuel economy estimates (Anable et al, 2014).

For some, technology is an attractive feature, particularly ‘the opportunity to engage with new, cutting edge technology’ (Hutchins et al, 2013, in Anable et al, 2014).

Electric vehicles are perceived as having less environmental impact, through reduced noise and carbon emissions (Axsen and Sovacool, 2019). Symbolic aspects of EV ownership can act as a motivation, symbolising green credentials and being associated with a range of positive characteristics: 'lower resource consumption, independence from petroleum producers, advanced technology, financial responsibility … and environmental and/or resource preservation' (Anable et al, 2014).

Other motivations are changes and developments that reduce and remove barriers to purchase. As the proportion of electric vehicles on the roads increases, perception of electric vehicles can be changed through increasing experience and exposure and changing social norms (Anable et al, 2014). Fleet owners are out of scope of the current study but play an important role in increasing the market share of electric vehicles (Anable et al, 2014; Angeloudis and Stettler 2019).

Barriers

When asked about perceived disadvantages of electric vehicles, survey respondents most commonly mentioned concerns about: recharging (56%) including location, how to recharge and time needed to do so; batteries (40%) primarily the range or distance travelled on a single charge; and cost (29%), including purchase and running costs, and depreciation in value (29%). Recharging and battery (mainly range) concerns were higher in rural areas (48% versus 39% in urban areas). Cost concerns were more likely to be mentioned by men (35% versus women 24%) and those in higher social grades (ABC1 44% versus C2DE 37%) (Department for Transport, 2019).

Cost is an important barrier to buying an electric vehicle (Brook Lyndhurst. 2015) although buyers may be less sensitive to high purchase price, or capital cost, when offset against lower running costs (Anable et al, 2014). The majority of trial participants considered purchase price extremely important (PHEV- 35.5%, BEV 37.5%) or important (PHEV 49.5%, BEV 50.5%) when considering an EV (Beard et al, 2019). In this study, cost conscious greens were most sensitive to purchase price. In earlier studies, upfront costs were seen as likely to remain a barrier until at least 2030, particularly for BEVs (Element Energy, 2013). Although the total cost of ownership, including fuel and upfront costs, is currently no cheaper than ICE cars, this is expected to change by 2030 (Gov Off Sci, 2019b). There is mixed evidence on other costs, although maintenance costs were mentioned as a barrier, and resale value thought likely to become increasingly important as the market matures (Anable et al, 2014; Brook Lyndhurst, 2015).

Range anxiety – the concern that an electric vehicle won't have enough charge to complete a journey - is an important barrier to buying an electric vehicle (Anable et al, 2014; DfT, 2014, 2019), although some EVs have the range necessary to complete most journeys due to advances in EV and battery technology (Hirst, 2020). Range anxiety is potentially less of an issue with PHEVs (Anable et al, 2014). In UK based surveys, around 70% of respondents said that they would worry about not being able to travel as far as they needed (Bunce et al. 2014), although more recent surveys have found lower prevalence of recharging or battery/range concerns (Department for Transport, 2019).

Range anxiety also has an impact on how electric vehicles are used, as drivers might not use the full vehicle range: in a UK trial only 7% of journeys with BEVs were started with a battery with less than 50% charge, even though the journeys were all less than 48% of the minimum range of the vehicles used and so could have been completed without recharging (Anable et al, 2014). Beard et al (2019) found that, during a four-day trial, characteristics of journeys in BEV, PHEV and ICE cars were broadly similar, although participants usually started their journeys in BEVs with more charge due to battery size and having the option to use petrol in the PHEV.

Beard et al (2019) found that the majority of participants considered PHEV range (83%) and BEV range (98%) important, and that willingness to consider owning a PHEV or BEV increased as all electric range (AER) increased. For PHEVs, an AER of 50 miles would be needed for 50% of participants to consider a PHEV as a main car; and AER of 100 miles for 90% to consider a PHEV as a main car. For BEVs, participants required a higher mileage to consider a BEV even as a second car: an AER of 100-150 miles would be needed for 50% to consider it as a second car and an AER of 200 miles for 50% of participants to consider a BEV as a main car. A BEV with an AER of 300 miles or more would be needed for 90% of participants to consider it as a second or main car.

Availability of charging points was highlighted as a barrier in earlier research (Bevis et al, 2013; Bunce et al, 2014) but more recent studies have found that workplace and public charging infrastructure do not influence likelihood of buying a PHEV (Beard et al, 2019). Home charge-points are considered more important than work or public charge-points. Early analysis, based on the English House Condition Survey, indicated that 50% of urban households and around 95% of rural households have access to off-street parking (Element Energy, 2003). Brook Lyndhurst (2015) notes the geographical variation in charger use public chargers are under-used in some areas and in high demand in other areas, with reports of ‘charger rage’ in some parts of London. Long recharging time was also mentioned as a barrier by 70% of respondents (Bunce et al., 2014) with public slow charging facilities seen as an issue given the length of time parked in a public space (Anable et al, 2014).

The time required to charge is important. Beard et al (2019) found that willingness to buy a PHEV or BEV increased as charging time decreased. While 95% would consider a PHEV as a main car with 1 hour charge time required for 100 mile range, only 20% would do so if charge time was 8 hours. A similar pattern was found for BEVs. To appeal to 50% of participants as a main car a charging time of four hours for 100 mile range would be acceptable for PHEVs, and less than three hours for BEVs. Beard et al (2019) indicated that these charge times could be achieved with a ‘mode 3’ charging unit which are increasingly available as home chargers.

Concern about EV performance, including speed, practicality and looks, was seen as a barrier to EV purchase by a small proportion (3%) of respondents in the public attitudes tracker (Department for Transport, 2019) and noted in earlier studies (Anable et al, 2014) although negative perception of EV performance was improved after a short trial (Beard et al, 2019). Lack of familiarity with electric vehicles and this being a new, relatively unproven technology may become less of a barrier as EVs become more common (TNS-BMRB, 2014). In recent trials, both BEVs and PHEVs were rated higher on all dynamic performance (where drivers are actively engaged in driving using the accelerator) and cruising performance (where the driver maintains the current state without added acceleration), except for ‘sportiness’ where BEVs were rated lowest (Beard et al, 2019).

As well as practical concerns noted above, symbolic issues may also act as a barrier to purchase. Bunce (2014) noted that a positive stereotype of EV owners may be emerging, with EVs associated with innovativeness, positive social signalling, and a ‘green’ identity, but early research indicated that some consumers would be embarrassed to own an EV (Anable et al, 2011). Even more recently the potential for embarrassment of mockery has been noted for EV users, where the EV ‘is seen to conflict with norms and practices important to the user' (Axsen and Sovacool, 2019, p.11). However, Beard et al (2019) found that participants generally disagreed that they would be embarrassed to own an electric car.

4.6.3 Incentives

Anable et al (2011) identified government grants and extended warranties as the most popular incentives, with extended warranties seen as more effective in the early years. Financial incentives may be necessary to compensate for the relatively high cost of electric vehicles, bridging the difference between the cost of a new electric vehicle and a new ICE car, but incentives may not be enough to compensate for other barriers, such as limited range (Anable et al, 2014; Brook Lyndhurst, 2015). EV buyers showed high awareness of the Plug-in Car Grant (84%) and a small proportion (5%) mentioned the grant as a reason for buying an electric vehicle (Hutchins et al, 2013). Although EV owners may not report purchase price incentives as a reason for adopting a EV, literature suggests that most could not have adopted an EV without an incentive (Beard et al, 2019). More recently, Beard and colleagues (2019) used a choice experiments to explore the impact on financial incentives on likelihood to adopt a PHEV or BEV. They found that a 'government grant towards the purchase price was found to yield the highest average likelihood to adopt a BEV or PHEV (4.1 on a 5-point scale) for all three consumer segments included.

Other incentives, such as congestion charge exemption, have greater impact on day-to-day costs or in specific geographical areas. Anable et al (2014) noted that the impact of congestion charge exemption and parking-based incentives may be highly context dependent.

4.6.4 Impact

The proportion of newly registered cars that are alternate fuel vehicles, including plug in hybrid (PHEV) and battery (BEV) electric vehicles, has increased accompanied by an increase in the proportion of Ultra Low Emission Vehicles (ULEVs).The Society of Motor Manufacturers most recent figures recorded over 22,000 BEV and 14,500 PHEV registrations in the year up to May 2020, with these EVs accounting for 7% of the market share of newly registered cars (SMMT, 2020). This is likely to have a positive impact on emissions and on pollution. However, there is a lack of evidence on impact of EVs on car use and public transport more generally.

4.6.5 Evidence Gaps

Consumer characteristics and their motivations and barriers to purchase as EV are likely to change over time, eg as EV technology and infrastructure develop, and as the second hand EV market develops. The recent study by Beard et al (2019) captures several aspects of this exploring potential consumers' attitudes, perceptions and willingness to adopt BEV and PHEV before and after a four-day trial. The research draws out the impact of trialling EVs and the differences between consumer groups, and they note that further research is needed to explore the differences between consumers.

Anable et al (2014) also highlighted the need to better understand the decision-making process when buying new cars and the trade-offs, to identify which factors are most important in the decision to buy or not buy an EV. Future research could also be used to capture the role of symbolic factors (Axsen and Sovacool, 2019) and emerging factors linked to market development, e.g. resale value.

Brook Lyndhurst (2015) highlighted the need to understand the impact of incentives, potentially through choice experiments examining response to different packages of financial and non-financial incentives. Beard et al (2019) use a choice experiment to explore some of the factors around willingness to purchase BEVs and PHEVs, including incentives. However, it would be useful to better understand the choices made by EV owners.

4.7 Electric bikes

4.7.1 Consumer characteristics

Information about electric bike use in the UK is predominantly from small scale trials and bikeshare schemes. A report by Carplus Bikeplus (2018) on eleven shared e-bike schemes in England and Wales provides valuable insight into user characteristics, journey type, barriers, motivations and incentives, although it is worth noting that the findings are based on shared electric bikes rather than personally owned electric bikes and user characteristics may reflect this. Although based on a small number of schemes, the study captures information from a diverse range of shared e-bike schemes in towns, cities and rural areas serving visitors and regular users. Percentages are included for information, although should be treated as indicative as the sample is not representative of the general population. The sample comprised of one off and regular users of the eleven selected schemes over a one-year period. The shared e-bike scheme affords some understanding of the characteristics of those who choose to use an e-bike. Overall,188 electric bikes were provided, and these were used by 2,667 people over 11,702 journeys. Short surveys were used to collect information from riders directly after use (visitors) or after a short period of use (regular riders), and travel data was collected using GPS. Around 20% of riders completed a survey, 470 individuals, including 65 regular riders who completed a baseline and follow up survey.

Demographic characteristics

Electric bikes had broad appeal. Almost half (45%) of those using shared e-bikes were women, and it appeared that women were more likely to use an electric bike than a standard bike (25%, NTS 2015). Electric bikes appealed to users across the age range, with 90% of users aged 25 to 64. Of 2,667 users in the eleven schemes: 3% were aged 16-24, 17% aged 25-34, 29% aged 35-44, 25% aged 45 to 54, and 19% 55-64, 6% aged 65-74, none were 75 or older. Those aged 35 to 64 showed relatively high electric bike use when the age profile of electric bike users was compared with that of the UK general population.

The e-bikes were also used by non-cyclists – one in three users agreed with the statement that they ‘rarely or never’ cycled before using a shared e-bike. This group were classed as ‘reluctant riders’ based on the classification of users in the CycleBoom study which described this group as riders who had ‘not cycled in the last 5 years or had either stopped or substantially decreased their cycling’ (CycleBoom, 2016). The definitions are based on biographic interviews with older adults and examples of reluctant riders include those who stopped cycling in early adulthood and now use car or public transport out of habit, those who cycled during their working lives but are now retired or working further away, and those who are reluctant to cycle due to concerns about traffic safety, or due to ill health. ‘Reluctant riders’ cited safety concerns and lack of enjoyment as barriers to returning to cycling and mentioned that training might be an effective way to increase confidence to cycle (CycleBoom, 2016). It is interesting to note that comments from non-cyclists noted the enjoyment and increased confidence they felt while using electric bikes (Carplus Bikeplus, 2018).

E-bikes were also accessed by people whose health or fitness made it difficult for them to use a standard bicycle (26% of users) and were used to aid recovery, for example from long term illness or knee injury or pain. Adapted e-bikes, such as hand pedal electric assist bikes, two-person trikes and wheelchair carrying bikes were available at one scheme in the New Forest and case studies described their use by a young adult with learning difficulties and a parent with MS.

E-bikes also provided an important means of transport for those with low incomes and enabled shift workers to travel to and from work where public transport did not fit with their working hours. Among regular users – around half of the group – around 18% were young adults not in education, employment or training (NEETs) and a further 18% worked part-time.

Attitudes and beliefs

Both shared e-bike schemes and small-scale trials revealed an emotional response to using e-bikes and to their travel data. Overall, 41% of shared e-bike users reported feeling happier when using an e-bike (Carplus Bikeplus, 2018). Longer term trial users were interested in viewing their personal mobility data and appeared to experience feelings of achievement, inspiration and pride in response to their ride data (Behrendt, 2016).

Social aspects of e-bike use and networking were also apparent in small scale trials. Users were motivated to share their data with others in the trials and enjoyed feeling part a group of riders. Trial users mentioned that they would like to share more widely, with friends and family (Behrendt, 2016).

Behavioural, including typical journey behaviours

In the shared electric bike trial, levels of car ownership appeared higher among shared e-bike users (87%) than the general population (74%). This may be partly due to the location of schemes, some of which were in tourist areas accessible by car, e.g. the New Forest, and likely to appeal to visitors as a way to explore the area.

Journey characteristics

The eleven shared e-bike schemes covered a range of areas and users: around half were visitors, or one-off users, while half were regular users who used their e-bike at least once a week, including 39% who used their e-bike three or more times a week (Carplus Bikeplus, 2018).

It appeared that e-bikes allowed riders to make longer and more challenging journeys than they would on a standard bike. The average journey made on e-bikes was 5 miles, compared with an average journey on standard bikes of 3 miles. One third (33%) of regular users cycled up hills they would not have managed on a standard bike (Carplus Bikeplus, 2018).

4.7.2 Motivations and barriers

Motivations

The demographic characteristics of shared e-bike scheme users illustrate the accessibility of e-bikes to men and women across the age range, and their use by those who do not regularly use standard bicycles or struggle to do so because of health or fitness.

Shared e-bike users were motivated to use e-bikes for a range of reasons, including exercise (37%) and enjoyment (34%). They also reported practical reasons for this choice, including to reduce journey time (28%), for convenience (23%), to save money (22%) and because they are easy to park (17%).

Ognissanto et al (2018) found activity levels on e-bikes were lower than for standard bikes, around a quarter (24%) of the energy of a standard bike, but overall reported that most users reached at least moderate intensity exercise levels. ‘Although less physically demanding than conventional bicycles, several studies have shown that riding an e-bike also provides health benefits’ (Ognissanto et al, 2018, p25). Among shared e-bike scheme users who were motivated by physical health and wellbeing, 37% reported using the e-bike for exercise and 34% to make their journey more enjoyable (Carplus Bikeplus, 2018).

The lower activity levels than standard bikes may be an advantage in making e-bikes accessible to a wider population and allow users to make longer and more challenging journeys. This could make commuting easier for people who currently live too far from their workplace for them to cycle. One-off and regular users of e-bike schemes reported that the e-bike improved their journey through shorter travel time (28%), convenience (23%), lower travel costs (22%), easier parking (17%), and being able to complete long journeys (16%). Regular users who commuted by e-bike also enjoyed being able to cycle to work without getting sweaty (26%).

The advantages of using e-bikes continued with longer term use. Regular users who used their e-bike at least once a week for a longer period, were motivated to use their e-bike to be more active (34%), have shorter journey times (35%), travel longer distances (33%), to cycle up hills (33%) and to inaccessible places (13%). For regular users e-bikes also provided a means of switching transport mode, with 22% actively using their e-bike to reduce their car use.

In trials where users had access to e-cycling data more than half viewed their ride data. Users said they were motivated by viewing their travel data, by sharing it with others and by feeling part of a group of users (Behrendt, 2016). Behrendt (2016) noted the growing social practice of sharing mobility data by e-cyclist and the importance of sharing ride data for trials users, both with family and on social media. The comments from the riders were seen to ‘show how networked practices become an integral part of activities that were traditionally understood as ‘offline’, such as cycling’ (Behrendt, 2016, p.162).

Barriers

Barriers mentioned included the cost of buying an e-bike, the challenge of maintenance and repair and the real or perceived effort of cycling. Although response to e-cycling data was primarily positive there were some concerns around privacy and the use of personal data. Storage was mentioned as was this raised mainly by those using e-bikes via shared schemes, as a barrier to owning an e-bike.

4.7.3 Incentives

The wider appeal and accessibility of e-bikes through shared schemes potentially allows these shared schemes to reach a broad range of users in different environments. The opportunity to try out an e-bike allows potential users to experience and gain confidence in e-bikes, removing barriers to use. Targeted schemes, including a 'try before you buy' use over a one-month period, a scheme set in an area of social housing, work-based schemes and shared bikes in tourist areas, allow e-bike schemes to be tailored to different groups of users (Carplus Bikeplus, 2018).

The Carplus Bikeplus study amongst 2,667 users of 11 shared bike schemes noted a number of strategies to support and encourage e-bike use. They stressed the importance of offering shared electric bike schemes to provide convenient and relatively low cost cycle hire as well as the need to place electric bikes in different locations: in work environments to encourage people to use them for commuting, first and last mile journeys and travel between sites; in residential locations to support accessibility, e.g. in rural areas, and in tourist locations, to encourage recreational use (Carplus Bikeplus, 2018).

The Carplus Bikeplus study highlighted the effect of using a shared bike scheme. Overall, 29% of all shared e-bike scheme users who completed a follow-up survey (n=470) said they would be more likely to buy an e-bike after using one. 85% of regular users who completed a follow-up survey (n=65) said they would be more likely to buy an e-bike after using one – this finding needs to be treated indicatively due to the low sample size. There was evidence of regular users actually purchasing an e-bike (15% of 65 regular users) or standard bike (17% of 65 regular users) after the scheme. The study notes that the electric bike may have allowed users to move on to using a standard bike after overcoming concerns about their fitness. Shared e-bike schemes also provide a way of users continuing to access e-bikes where there are barriers to owning one, such as storage.

4.7.4 Impact

There was some evidence that shared e-bikes encouraged mode shift, with 46% of all respondents using their e-bike for a journey they had previously made by car as a driver, passenger or in a taxi: this included one-off as well as regular users. Around one fifth (22%) of regular users reported that they were actively using the e-bike as a tool to reduce their car travel. Although this hints at the potential for electric bikes to reduce car use, the selected references did not provide any detailed information about the impact of electric bikes on road use (Carplus Bikeplus, 2018).

Ognissanto et al (2018) modelled the economic and health impact of e-bike usage although the lack of UK based e-bike data made it necessary to base assumptions on international data for risk levels and characteristics of standard bikes, with some adaptation. Assuming one in ten users (around 6,000 in total) in an average town shifting their commute to an e-bike, 'the health benefits of improved physical activity would be equivalent to preventing 3 premature deaths each year' and result in a financial benefit from health savings of around 12 million Euros a year. 'In economic terms … this implies that the cost of purchasing the e-bikes would be paid back within the first year, assuming a purchase cost of less than 2000 euros' (Ognissanto, 2018, p. 44).

4.7.5 Evidence gaps

More evidence is needed from shared e-bike schemes, potentially including longer term follow up research with users. The Carplus Bikeplus study (2018) covered the first year of the scheme (2016) so updates from this study would be invaluable in understanding the characteristics of users, journeys, motivations and barriers, mode shifts and to understand the impact of different types of scheme. The Carplus Bikeplus study identified two key areas of future research using shared e-bike schemes to improve accessibility in 'closed community' residential accommodation, such as a new housing development or student accommodation, and in rural areas. It would also be helpful to collect more data on e-bike owners, including their characteristics, the motivations for buying their own e-bike and how the bikes are used.

Propensity to cycle maps are designed to understand suitability of different active travel options for the built environment (Ognissanto et al, 2018). The tool is used to estimate the potential for cycling in different locations to guide investment and interventions designed to support and increase levels of cycling. Using travel to work data from the 2011 Census, the propensity to cycle tool covers the level of cycle use in commuting, mortality rates for new and existing cyclists and commuting distance and gradient. Propensity to cycle maps adapted to include electric bikes (Ognissanto et al, 2018) would be useful to understand suitability of areas for e-bikes, to plan investment and interventions to support e-bike use.

4.8 E-Scooters

At the time of writing, it was not legal to use e-scooters on public roads or on footpaths and there was a lack of evidence on e-scooter use in the UK. The Department for Transport had planned e-scooter trials in four Future Transport Areas, designed to collect data on the characteristics of users and journeys, as well as the motivations and barriers to e-scooter use (The Guardian, 16 March 2020). However, since COVID-19 the UK legislation has been amended to allow rented e-scooters to be used on UK roads in more areas and sooner than initially planned (see Department for Transport, 2020 for details of the consultation outcome).

We did not identify any studies of e-scooter use in the UK apart from one small scale trial which allowed 18 TRL staff and a range of scooters, including one electric scooter. Most of the staff were interested in trying the electric scooter and indeed preferred it to other micro-scooters. It was not possible to separate the findings for electric scooters from scooters in general. Scooters, including the e-scooter, were used for recreational journeys (15 of the 18 users) as well as for specific journeys such as a commute, trip to a shop or gym (8 of the 18 users).

In the TRL trial standard and electric scooters were seen by the 18 staff as enjoyable, quicker than walking and more portable than bicycles (although acknowledged the challenge of having to keep these with them). Users mentioned not being able to use the electric scooter legally on public roads or pavements as a barrier, as was not being able to use the electric scooter in the rain. One mentioned the electric scooter being unpredictable when the motor started and not suitable for use by younger children, although acknowledged that children would want to use them. The discomfort of using a scooter with small wheels on uneven surfaces was also mentioned by one user, as a barrier to using the scooter for regular commuting.

There is some anecdotal evidence of impact from the trial. Trial users were asked if they would use a scooter to replace other modes of transport. Overall, having tested a range of scooters, users said they would (5 of the 18) or may (10 of the 18) use a scooter in place of other modes of transport and users commented that they might use a scooter to replace longer journeys, or those taken by bicycle (TRL, 2018).

5 Conclusions

This study focusses on transport uptake in the UK and covers a diverse range of transport types from cars to micro-mobility, from new and emerging transport to relatively well-established forms, and from private, personal transport to public or shared transport. It also includes transport types just emerging in the UK (Citymapper Pass) or not legal for use in public areas (electric scooters). The profile of users, their motivations and barriers reflect this diversity. However, this section seeks to bring together common themes across the different transport types.

5.1 Consumer characteristics

Consumer characteristics
Stakeholders noted that the demographic characteristics of users of new transport technologies were comparable to those of early adopters. Users were generally more likely to be male, young to middle aged, urban and to be technophiles, or comfortable with technology. It has also been noted, e.g. for electric vehicles, that the characteristics of early owners may differ from those of later adopters. As the technologies become more common, they will be used by a wider range of people, and some of the current barriers to use may be reduced or eliminated. However, it is likely that some barriers, like the relatively high purchase price of electric vehicles, will remain in the short to medium term and cost of access will shape the users.

Non-users
Stakeholders described non-users as those with the greatest barriers to use. While this might be obvious it is also important as there are some demographic groups, such as older adults, adults with a disability and those on low incomes, who experience greater barriers across a range of transport types. As some of the key barriers, including cost of access, digital exclusion and living in a rural location, are common across several transport types, inequality of access and the risk that some groups have significant barriers to using any of these technologies are an important consideration.

Variation by transport type
There were variations by transport type which suggests that different transport technologies will continue to appeal to different types of users. Variations by transport type are associated with other factors, including attitudes and values, geographical factors and typical journey behaviour.

These new transport technologies can provide better transport options for key groups. Demand responsive transport was an important service for those in rural areas with less dense public transport systems, particularly for those who don't have access to a car. Shared electric bike schemes also have the potential to improve accessibility for shift workers and those on low income: around one fifth of regular users of shared e-bike schemes were part time workers who were able to use electric bicycles to travel when public transport was less frequent, a further fifth were NEETs (young adults who are Not in Education Employment or Training).

Attitudes and beliefs
Attitudes and beliefs likely to affect transport use include attitudes to sharing, attitudes to driving and the symbolic factors, or how transport type reflected user identity and personality. Automated vehicles and electric vehicles both appealed to people most open to new technology, while being comfortable with technology and having smartphone access was essential for access to MaaS and

to app-based taxis. Having pro-environmental beliefs was associated with uptake of electric vehicles and shared transport services.

Stakeholders suggested that the shared values and mindset of different generations (e.g. baby boomers, millennials) were associated with using different types of transport. Views around vehicle ownership, whether a car is seen as a reflection of personality (symbolism) and enjoyment of driving are likely to vary across generations. It's also likely that such variation reflects life stage and household characteristics, e.g. having a family, or being able to drive. Electric vehicles, for example, were associated with family and multicar households, and demand responsive transport with older adults.

Access and availability
Finally, access and availability to transport were fundamental, and linked to geographic factors, e.g. living in an urban or rural location. Urban areas tend to offer richer, denser public transport networks and, from a business perspective, are more profitable places to develop new forms of transport, such as car share and bikeshare. Poor transport networks outside of urban areas may be a barrier to some technologies, e.g. MaaS, both in terms of development and user uptake. However, electric vehicles may be more appealing outside of cities where concerns over range and charging are offset by higher levels of off-street parking.

5.2 Journey type

Journey types vary across the different transport technologies. Electric vehicles, for example, were used for different types of journeys including commuting, shopping, leisure and visiting friends and family. However, range anxiety meant that the full range was not used, with users less likely to start a journey with only 50% charge even if there was sufficient range to complete their journey. Conversely, electric pedal assist bikes allowed users to extend their journeys, to cycle up hills and to commute to work without getting sweaty. Demand responsive transport was used for a range of journeys, and often in areas with no public transport alternative. Car clubs were typically used for shorter journeys, but stakeholders noted that users would prefer to be able to use these for longer trips.

5.3 Motivations and barriers

Motivations

Motivations for using new transport technology included saving money, finding transport that better met their needs, and the opportunity to try out new transport and ease of use.

Cost savings were salient for shared transport, e.g. shared bike schemes, car sharing and also for electric vehicles, where fuel cost savings were a motivation despite the high purchase price.

New transport was more likely to be used when it better met user needs than existing transport. Demand responsive transport is likely to have higher uptake in rural areas where public transport may not meet user needs because of access or cost.

Trying out a new type of transport was an important motivation. Trialling an electric vehicle reduced users' negative perceptions and concerns about vehicle technology and performance. After using a shared electric bike, one-off and regular users were more likely to consider buying an electric bike in future. Shared electric bike schemes also appealed to those who had never or rarely cycled before, around one third of users making bikes accessible to a wider group.

Both digital and personal social networks were important for diffusion of technology and setting or adjusting social norms. Electric bikes users were motivated by viewing and sharing their trip data with other users and with family and friends. Social norms also had an influence on uptake. Uptake of electric vehicles was associated with having electric vehicles in the neighbourhood.

Barriers

A range of barriers were identified, including access and availability, cost, the effort of switching, technology, data security and safety. Addressing the barriers is important for transport use in general and to prevent inequality of access.

Cost was a barrier for some transport types, particularly for privately owned automated vehicles and for electric vehicles which had a high purchase price, although it is likely that the high cost of AVs means they will be available as shared rather than privately owned transport. Although purchase price (and insurance costs) are a barrier to car ownership, particularly for younger people, this barrier may be reduced as vehicles become more established and the second-hand market develops. However, the cost barrier may preclude access for those on lower incomes who might benefit most from using autonomous vehicles, including older people and people with disabilities.

Using the internet or a phone application to access transport was a barrier, more likely to affect older adults although this barrier may be reduced over time. Levels of digital exclusion may partly reflect context, e.g. older adults living in cities and using public transport may be less likely to experience this barrier.

The effort, or cognitive load, involved in switching to a new transport type may be a barrier to using a new technology. This was mentioned in connection with mobility as a service, as most journeys are habitual, and the effort involved in planning and switching to a new mode, or multiple modes, may be off-putting.

Concerns about data security and privacy were a barrier to transport technologies, particularly those that were connected, including automated vehicles and electric bikes.

Personal security was a barrier to using shared transport services, particularly for women, although less so for younger adults. Stakeholders noted that shared services targeted at existing social groups, e.g. people working for the same company, or living in the same village or local area, may be effective at reducing such barriers.

5.4 Incentives

Uptake of transport technologies can be shaped by incentives. ‘Carrot’ incentives, such as the plug-in car grant for electric cars, free parking for electric vehicles at workplaces and a ‘try before you buy’ scheme for electric bikes are useful to encourage uptake. Trying out an electric vehicle was also found to increase likelihood of buying an EV, although the impact varied by EV type, consumer type and whether the EV would be main or second car.

‘Stick’ incentives including the London congestion change zone, and ultra-low emissions zone are important in moving people away from vehicles with high emissions and towards other transport options, such as electric vehicles and public transport.

5.5 Impact

It is difficult to establish the impact of transport technologies on existing transport use as they are not well established in the UK. However, stakeholders indicated that uptake of new technologies may have undesired impacts, e.g. app-based taxis reducing public transport use and increasing congestion.

5.6 Evidence gaps

Some of the transport technologies covered in this study are relatively new or not yet available in the UK, therefore there was limited evidence relating to their uptake in the UK. The rapid evidence assessment focused only on the most relevant literature which should be taken into account in considering evidence gaps and implications for future research. The study and stakeholder interviews identified evidence gaps and areas of development:

- There is a need for further research to better understand people's behaviour, values and motivations when choosing whether to use these technologies when they are more widespread in the UK. This might involve qualitative research to understand what people want from future transport technologies, what they value about the transport they currently use and how this affects the level of interest in and uptake of future transport technologies. Marshall et al (in publication) carried out a study for DfT to understand decisions around Shared Mobility which could be applied to other transport modes.
- The characteristics of current users tend to reflect the early adopters of these new and emerging transport modes. Further research is needed to understand consumer characteristics as these transport technologies become more widespread as the characteristics, barriers and motivations of later consumers are likely to differ from those of early adopters. Understanding the concerns of a wider range of consumers is essential as failing to do so could lead to the development of services that do need meet the needs of end users, or worse could make these systems less accessible, which has potential significant implications for the integration and uptake of these new technologies.
- Additional research is also needed to understand how consumer characteristics differ between transport modes. It is important to understand whether these transport types compete for the same users or appeal to different groups as competing for the same users may reduce the uptake and potential impact of new transport types. Linked to this is a need for research into how to widen the appeal of different transport types.
- We note that some of the transport modes covered in this study include several different components, e.g. shared transport includes ride pooling, ride share, car share and bikeshare, and the transport types offered within a particular MaaS service are likely to depend on the transport modes available in that area. Furthermore, questions about likelihood of adopting a particular transport mode, such as AVs, often rely on 'self-imagined' scenarios which are likely to vary from person to person. Clear definitions of the different transport modes are an important basis for this research, to ensure that respondents are thinking about the transport types in the same way and to clearly differentiate between different modes.
- Insight into the uptake of technologies that are still emerging, e.g. MaaS AVs, is often based on hypothetical propositions, asking people what they think they might do based on 'self-

imagined' scenarios. Experts suggested 'real world' research is needed to understand what people actually do, as has been tried with MaaS.

- Additional research could also be used to understand how experiencing a new transport type influences uptake and the perceived motivations and barriers to using different transport modes – are people more willing to use a new type of transport after they have had a chance to try it? Being able to try out a new mode of transport can encourage uptake, although the impact varies by transport mode. For example, participants in an EV trial were more likely to choose a PHEV as a main or second car after a four-day trial, and more likely to choose a BEV as second car, but they were less likely to choose a BEV as a main car.
- More research is needed to identify and address barriers to use of these technologies. Stakeholders noted that non-users were those with the greatest barriers to use. Some barriers, e.g. digital exclusion, having a lower income or living in an area with poor public transport networks, apply to several transport modes and so limit choices in these groups. As stakeholders pointed out availability can also be an issue, it should not be assumed that rural, older, less affluent people would have any particular resistance to these technologies were they available in the areas where they lived, but rather uptake was lower in areas of less population density because transport technology schemes were less commercially viable. The study highlighted some useful first steps including bike schemes set in social housing and developing shared transport for existing social groups as well as demand responsive transport in rural areas.
- Linked to this, stakeholders also suggested carrying out more research involving older adults to better understand their specific barriers and transport needs. Older adults, particularly those aged 75 and over, are less likely to personally a smartphone, more likely to have mobility problems and may have fewer transport options, particularly if they are unable to drive. Access to free travel in this age group is also likely to affect transport choices.
- Experts also highlighted the need to understand how to highlight best practice on providing these transport technologies across the UK, e.g. car clubs or shared bike schemes, and to apply this in different types of area, e.g. cities outside London, and in rural areas.
- There was a lack of evidence on e-scooters. The Department for Transport is working with Local Authorities and e-scooter operators to deliver e-scooter trials. The Department for Transport will contract and manage monitoring and evaluation activities to build evidence on safety, public perceptions and the wider impacts of e-scooters to inform future policy making. More research would be welcome to understand barriers to use and what could encourage uptake.
- It would be helpful to examine international evidence wherever a technology is more prevalent in other countries.

Relevant research and trials of new technologies highlighted by stakeholders include:

- Shared transport research by Como UK (https://como.org.uk/) who are involved in the UK's transition to integrated mobility solutions, including shared transport, and regularly publish research including annual surveys of users from car clubs and bikeshare schemes
- Surveys of LiftShare and Zipcar users (eg Liftshare: https://www.intelligenttransport.com/transport-news/98788/almost-half-of-people-to-change-commuting-habits-finds-uk-survey/, Zipcar https://www.zipcar.com/press);

- The Transport Systems Catapult Traveller Needs and UK Capability Survey (covered in this study: https://ts.catapult.org.uk/current-projects/traveller-needs-uk-capability-study/)
- An upcoming paper by Morton and colleagues exploring spatiotemporal factors in uptake – how temporal variation in London Bikeshare is impacted by working conditions and quality levels

Trials of new technologies were also mentioned:

- Flourish project (http://www.flourishmobility.com/) a UK based project that implemented driverless cars
- WHIM trial of MaaS in West Midlands started in 2018. For more information about the WHIM project see: https://whimapp.com/about-us/. For information about the app plans and travel options available to WHIM users see: https://whimapp.com/plans/)
- Triangulum Project in Manchester (http://www.triangulum-project.eu/). The Triangulum project is a European Smart Cities project looking at developing and implementing smart cities. Manchester, UK is one of three 'Lighthouse Cities' selected for testing approaches to sustainable mobility, energy, ICT and business opportunities.

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Appendices

Appendix A. Search strings

The literature search was carried out between October and December 2019. The search strings we used are set out in the tables below. Table A.1 shows the search strings used in the Google and Google Scholar search. Table A.2 shows the search strings used the website search. Table A.3 shows the search strings used to search the academic database, EBSCO.

Table A.1 Searches carried out in both Google Scholar and Google

Transport types	Search string
Shared transport services	(“shared transport” OR “ride sharing” OR “car sharing” OR “bike sharing”) AND (uptake OR use OR users OR consumers)
Connected or autonomous vehicles	(driverless OR self-drive OR automated) AND car AND (uptake OR use OR consumers OR users)
Connected or autonomous vehicles	(“Connected vehicle” OR “autonomous vehicle” OR “drive assistance” OR “driver assistance”) AND (uptake OR use OR consumers OR users)
Mobility as a Service	("mobility as a service" OR MaaS) AND (uptake OR use OR users OR consumers)
Mobility as a Service	("mobility as a service" OR MaaS) AND (uptake OR use) AND ("UK" OR "United Kingdom" OR "Britain" OR "England" OR "Wales" OR "Scotland" OR "Northern Ireland")
Electric cars	("electric cars" OR "electric vehicles" OR "electric mobility") AND (uptake OR use OR users OR consumers)
Electric cars	("electric cars" OR "electric vehicles" OR "electric mobility") AND (uptake OR use) AND ("UK" OR "United Kingdom" OR "Britain" OR "England" OR "Wales" OR "Scotland" OR "Northern Ireland")
Electric scooters/bikes	("micromobility" OR "electric scooters" OR "e-scooters" OR "electric bikes" OR "e-bikes") AND (uptake OR use)
Electric scooters/bikes	("micromobility" OR "electric scooters" OR "e-scooters" OR "electric bikes" OR "e-bikes") AND (uptake OR use) AND ("UK" OR "United Kingdom" OR "Britain" OR "England" OR "Wales" OR "Scotland" OR "Northern Ireland")
App based taxi/minicabs	(Taxi OR mini-cab OR Uber) AND (app OR application) AND (uptake OR use OR user)
App based taxi/minicabs	(Taxi OR mini-cab OR Uber) AND (app OR application) AND (uptake OR use OR user OR consumer)
Dynamic/flexible transport	(“Demand responsive transport” OR “flexible transport”) AND (uptake OR use OR consumers OR users)

Table A.2 Searches carried out in EBSCO

Search string
"Mobility as a service" OR MaaS OR "connected vehicle*" OR "autonomous vehicle*" OR "self-drive car*" OR "self drive car*" OR "shared transport*" OR "ride sharing" OR "ride-sharing" OR "car sharing" OR "car-sharing" OR "demand responsive transport*" OR "flexible transport*" OR "app based taxi" OR "app based minicab" OR "electric vehicle*" OR "electric scooter*" OR "electric bike*" OR (app AND taxi) AND Uptake OR user* OR consumer* AND ("united kingdom" or UK or britain or british or english or scottish or scots or welsh or england or scotland or wales or "northern ireland" or ulster).
"Mobility as a service" OR MaaS OR "connected vehicle*" OR "autonomous vehicle*" OR "self-drive car*" OR "self drive car*" OR "shared transport*" OR "ride-sharing" OR "ride-sharing" OR "car sharing" OR "car-sharing" OR "demand responsive transport*" OR "flexible transport*" OR "app based taxi" OR "app based minicab" OR "electric vehicle*" OR "electric scooter*" OR "electric bike*" OR (app AND taxi) AND Uptake OR user* OR consumer*

Search string
"Mobility as a service" OR MaaS OR "connected vehicle*" OR "autonomous vehicle*" OR "self-drive car*" OR "self drive car*" OR "shared transport*" OR "ride sharing" OR "ride-sharing" OR "car sharing" OR "car-sharing" OR "demand responsive transport*" OR "flexible transport*" OR "app based taxi" OR "app based minicab" OR "electric vehicle*" OR "electric scooter*" OR "electric bike*" OR (app AND taxi) AND ("united kingdom" or UK or britain or english or scottish or scots or welsh or england or scotland or wales or "northern ireland" or ulster) AND (incentiv* OR encourag* OR motive OR motivat* OR promot*)
"Mobility as a service" OR MaaS OR "connected vehicle*" OR "autonomous vehicle*" OR "self-drive car*" OR "self drive car*" OR "shared transport*" OR "ride sharing" OR "ride-sharing" OR "car sharing" OR "car-sharing" OR "demand responsive transport*" OR "flexible transport*" OR "app based taxi" OR "app based minicab" OR "electric vehicle*" OR "electric scooter*" OR "electric bike*" OR (app AND taxi) AND ("united kingdom" OR UK OR britain OR english OR scottish OR scots OR welsh OR england OR scotland OR wales OR "northern ireland" OR ulster) AND (impact OR impacts OR influence OR consequence OR consequences OR transform*)

Table A.3 Website searches

Website	Search string/approach
https://highwaysengland.co.uk/research-publications/	*No search string* - reviewed all publications on website
https://www.tsu.ox.ac.uk/pubs/	*No search string* - reviewed all publications on website
https://www.itf-oecd.org/search/research?f%5B0%5D=field_publication_type%3A637andf%5B1%5D=field_publication_type%3A646andf%5B2%5D=field_publication_type%3A645andf%5B3%5D=field_publication_type%3A2350andf%5B4%5D=field_publication_type%3A647andf%5B5%5D=field_publication_type%3A2349andf%5B6%5D=field_publication_type%3A317	*No search string* - Combination of: Key Words (transport types; use/uptake), Date Range (2010-2019), Filters on Website (Technology, Innovation; Traffic Volume, Usage, Demand; All Transport; Sustainability, Environment; United Kingdom)
https://mergegreenwich.com/category/news/	*No search string* - reviewed all publications on website
https://www.urbantransportgroup.org	"Mobility as a service" OR "connected vehicles" OR "autonomous vehicles" OR "self-drive cars" OR "shared transport" OR "car sharing" OR "demand responsive transport" OR "app based taxi" OR "electric vehicles" OR "electric scooter" OR "electric bike"
https://www.transportenvironment.org/publications	*No search string* - filter publications by : issue ('air polution' 'climate change') transport mode ('cars' 'fuels' 'public and urban') types of publication ('consultant report', 'TandE report')
https://www.trl.co.uk/	"Mobility as a service" OR "connected vehicles" OR "autonomous vehicles" OR "self-drive cars" OR "shared transport" OR "ride sharing" OR "car sharing" OR "demand responsive transport" OR "flexible transport" OR "app based taxi" OR "app based minicab" OR "electric vehicles" OR "electric scooter" OR "electric bike"
https://www.coventry.ac.uk/research/areas-of-research/institute-for-future-transport-and-cities/our-research/	MaaS connected vehicles autonomous vehicles self-drive cars shared transport ride-sharing car sharing demand responsive transport / flexible transport app based taxi app based minicab electric vehicles electric scooter electric bike
https://www.ucl.ac.uk/bartlett/energy/	MaaS / connected vehicles / autonomous vehicles / self-drive cars / shared transport / ride-sharing / car sharing / demand responsive transport / flexible transport / app based taxi / app based minicab / electric vehicles / electric scooter / electric bike *"/" denotes separate search.*

Appendix B. Screening tool

The inclusion criteria used for the initial search and title and abstract review are shown in Table B.1.

Table B.1: Inclusion criteria for title and abstract and review.

Apply screening codes in order below		**Description of screening criterion**
0	**Language**	*Include studies in English. Exclude studies not in English*
1	**Published**	*Include studies published in peer-reviewed journals or unpublished*
2	**Date**	*Include studies with a post 2010 publication date, or data gathered post 2010.*
3	**Setting**	*Include studies with data collected from the UK*
4	**Measure**	*Include studies with a measure (qualitative/quantitative) of potential/actual uptake of new transport technologies.* *Include studies that use empirical evidence (e.g. essays or opinion pieces are to be excluded from the review). Case studies can be included.*
5	**Focus**	*Include studies with a focus on uptake of new transport technologies.* "New transport technologies" that should be the focus of the review are: • Mobility as a Service (MaaS): a user-centric, intelligent mobility management and distribution system, in which an integrator brings together offerings of multiple mobility service providers, and provides end-users access to them through a digital interface, allowing them to seamlessly plan and pay for mobility. • Connected and autonomous vehicles, including driver assistance features, semi-autonomous features; • Shared services (internet-arranged/ app-based) e.g. ride-sharing; car sharing • Demand responsive transport services (internet-arranged/ app-based): Providing shared transport in response to requests from users specifying desired locations and times of pickup and delivery. • App-based minicab services; • Electric vehicle; Electric scooters; and Electric bikes

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Appendix E. Stakeholder interviews: Stakeholders and Topic Guide

We would like to thank the fifteen stakeholders contributed to this study by taking part in an in-depth interview, including those named below:

- Dr Noam Bergman, Lecturer in Energy Policy, University of Sussex
- Dr Tom Cohen, University College London (now University of Westminster)
- Beate Kubitz, Independent consultant
- Professor Glenn Lyons, Mott MacDonald and UWE Bristol
- Helen Morris, Integrated Passenger Transport Unit, Essex County Council
- Craig Morton,
  Lecturer – School of Architecture, Building, and Civil Engineering – Loughborough University
- Dr Charles Musselwhite, Swansea University
- Professor Graham Parkhurst, Centre for Transport and Society, University of the West of England, Bristol
- Professor Laurie Pickup, Vectos
- Charlene Rohr, RAND Europe
- Professor Tim Schwanen, University of Oxford
- Professor Sarah Sharples, Professor of Human Factors, Faculty of Engineering at the University of Nottingham
- Dr Chris Tennant, LSE
- David Williams, Managing Director, Underwriting and Technical Services, Axa UK

The topic guide used for stakeholder interviews is shown below:

Future of Mobility: Consumer characteristics and evidence gaps
Topic guide for stakeholder interviews

We wish to encourage stakeholders to discuss their knowledge of the evidence, views and perceptions in an open way, without excluding issues which may be of importance to the study. Therefore the questioning will be responsive to the issues raised in the course of the interview. The following guide lists the key themes, sub-themes, and questions to be explored at each interview. It does not include follow-up questions like 'why', 'when', 'how', as it is assumed that participant's contributions will be fully explored throughout in order to understand how and why views are held.
Discretion should be used regarding coverage of questioning. Some participants may have limited knowledge of some topic areas and some areas may not be relevant to all interviewees. Likewise, some stakeholders may be cautious about sharing ideas and knowledge of up-and-coming future research.

Text in italics denotes instructions to interviewer.

This research is about uptake of future transport technologies. It is designed to find out about the characteristics of people using new transport technologies, and to identify evidence gaps

Aims of the interview

Primary aims are:

- To identify which groups of people are likely to use new and emerging transport technologies
- To identify motivations and barriers for using these
- To identify gaps in our knowledge where further research is needed
- To find out existing work and when results will be available/published

Secondary aims are:

- To find out about incentives for using new transport methodologies
- To find out about the impact of new transport technologies on more traditional modes

Transport technologies of interest are:

- Mobility as a Service (MaaS)
- Connected and Autonomous vehicles; including drive assistance features
- Shared services, internet-arranged or app based, eg ride sharing, car sharing
- Demand responsive, flexible transport services, internet-arranged or app based
- App-based minicab services
- Electric vehicles
- Electric Scooters; electric bikes

Please ensure that you have read through information about the stakeholder, research interests and relevant publications, as well as the organisation they work for, before the interview. The review covers a wide area and we don't expect all stakeholders to cover everything, so this background information will be useful for probing relevant areas.

1. Introduction *(5 minutes)*

- Introduce self and NatCen
- Introduce the study: what is about (see aims and list of transport technologies above) and who it is for (DfT)
- Reassure the stakeholder that we understand that these are emerging fields, and so we are just as interested in the perceived evidence gaps as we are in what they know about the topic.
- How selected (via DfT, through search and from relevant publications)
- Talk through key points:
    - length of interview
    - interview like a discussion, although specific topics to cover
    - no right or wrong answers, your views are important
    - participation is voluntary and right to withdraw
    - recording interview so can listen and for accuracy
- Confidentiality and anonymity, secure transfer of data, how findings will be reported
- Any questions they may have

START RECORDING

- Confirm you have gone through information with them and they are to proceed

2. Background *(5 minutes)*
KEY AIM: To understand the stakeholder's background, role and knowledge in relation to the emerging technologies of interests.

Ask the stakeholder to give a brief background to themselves:
Prompt if necessary:

- Role
- Organisation
- Which, if any of the key technologies do they specialise in/ know about.
- Their research/policy interests in relation to transport and emerging transport technologies

3. Uptake of transport technologies *(20 minutes)*
KEY AIM: To understand the characteristics of people who use (and do not use) new transport technologies.

A discussion of the characteristics of people who use transport technologies

Start by asking stakeholder about characteristics of new transport technology users in general - it is fine for them to focus on the transport technologies they know most about, but do prompt to see if they are able to give information about other technologies of interest.

Please also prompt to find out the source of their information.

Characteristics
Prompt if necessary

- Demographic – e.g. sex, age, income, employment status, household type (single or family)
- Attitudes to transport – e.g. receptive to new technology
- Behavioural, e.g. occasional or regular traveller, commuter, travelling alone/with family
- Geographic, e.g. urban or rural, where in uk, which country/region

Type of journey technologies may be used for – e.g. short or long distance, urban/rural, regular commute or one off leisure trip, multiple forms of transport

Barriers or things that make it harder to use emerging technologies

Motivations or enablers, or things that make it easier, to use emerging technologies

Characteristics of non-users
*If it hasn't already been covered, please ask about characteristics of **non-users**, i.e. those less likely to use these technologies. Again, we're interested in the characteristics above: demographic, attitude behavioural, geographic, journey type, motivations and barriers.*

Prompt if necessary
Differences in characteristics of users across different technologies

4. Incentives and impact *(5 minutes)*
KEY AIM: to understand any incentives available for using new technologies, and the impact of new technologies on traditional modes.

These are secondary research questions – we are less likely to find evidence for these as we are looking at new and emerging technologies.

Awareness of incentives that are available for using any of the new transport technologies.

Awareness of the potential impact of these new transport technologies on more traditional modes.

Prompt if necessary
Differences in incentives/impact across different technologies

5. Evidence gaps and additional literature *(15 minutes)*

It's really important to DfT to understand where the current evidence gaps are, what research is being covered but not yet published, and what still needs to be covered.

KEY AIM: To understand the main gaps in the evidence and to get any recommendations for literature that should be included in the review.

Awareness of any work, evidence or research on future transport technologies that is currently available. Including grey, unpublished literature.

Awareness of any current, ongoing work, evidence or research on future technologies where results are forthcoming, either in publications or grey literature. Timeframe would be helpful, if offered - although sensitive.

Where do they believe are the main evidence gaps in the research around the uptake of new transport technologies and services.

Prompt if necessary
Evidence across different technologies

6. Looking forward and close *(10 minutes)*

KEY AIM: To identify any other areas we should be thinking about as part of the evidence review.

If you (or DfT) were to commission a piece of research around future transport technologies to fill the remaining evidence gaps, what would it be?

Can you recommend other stakeholders in the field that we should speak to as part of this review.

Any further thoughts

Thanks and close.

Appendix F. Stakeholder Interviews: Key findings

This section details the findings from the interviews with fifteen stakeholders. It begins by exploring their views on the characteristics of people who use future transport technologies, then moves on to consider perceived motivations and barriers to take up. It then looks at any incentive schemes to encourage engagement with future transport technologies, and their impact on traditional modes of transport. Finally, the section ends with an exploration of key evidence gaps and areas for further exploration.

Consumer characteristics

Stakeholders perceived that certain demographic characteristics and attitudes were more commonly associated with users of future transport technologies, both in general and by specific technology. On the whole, those who currently use or are more open to engaging with future transport technologies were considered to fit the typical profile of early adopters, that is, predominantly young to middle aged people who live or work in urban centres, who are confident using the internet, interested in and open to engaging with new technology, and more likely to be male than female and affluent rather than on lower incomes. However, underneath this broad trend, characteristics of those using particular types of future transport technology were more nuanced.

There was a view among stakeholders that a person's attitudes and values around mobility could be a stronger indicator of their likelihood to use certain technologies than traditional demographic segmentation along the lines of gender, age, income etc. This included a person's attitudes towards sharing transport, the extent to which they are optimistic or pessimistic (with the former being more likely to try new technologies), their attitudes towards driving (for example, whether they see it as an enjoyable activity in which they cooperate with other road users, or whether they see it as a combative activity, involving confrontation with other drivers) and what they value about the way they travel, including values around car ownership such as identity and privacy.

…you get a strong theme amongst some that they don't want to give up driving because they like driving and they like the experience and the freedom that they feel it gives them. You also get a strand who derive some sense of satisfaction from having a vehicle of their own, an opportunity to display their achievements perhaps, and that degree of personal autonomy is held dear, and the autonomous vehicle is seen as threatening that.

There was a view that segmentation by generation was a helpful way of understanding attitudes to using these technologies and therefore likely uptake by certain groups. It was suggested that the particular generation that someone belonged to (for example baby boomers, millennials, digital aboriginals) and the shared values and mindset of that generation, was key to understanding their likely behaviour in relation to transport technologies. For example, transport technology that required the use of a smart phone app or the internet were more likely to be used by generations who were familiar with and confident using the internet. Generation was also thought to be associated with attitudes towards sharing transport services, as for example, younger people were thought to be more open to the idea of using shared services (if there was a benefit to them, such as a cost saving), whereas older generations were more wedded to the idea of private ownership of their own vehicle.

However, there were views that it was not just the characteristics of the potential user, such as their generation, that influenced uptake, but also their mobility environment and access to transport services. For example, older people who lived in London were better-served by public transport than anywhere else in the UK, and so were more likely to engage with technology to top up their Oyster card than people of the same generation who lived outside of London who did not have that level of access to technology nor to such a dense public transport network.

It's a combination of the system, the technology and the people, that create an environment which changes who travels and in what way

Use of all types of transport technology was considered to depend on its availability in any given geographical area, which meant that many of these technologies were more likely to be used by people living or working in cities, where services such as bikeshare schemes, electric bike pools offered by employers, app based minicab services and car clubs were typically located, and where more effective public transport services made not owning a car more viable. Where bikeshare schemes were used in adjunct to public transport as a ‘last mile’ service, uptake was expected to be higher in cities where there was already a good public transport system. It was highlighted that just because certain demographic characteristics are over-represented in groups of people who live and work in cities (that is, they may by more likely to be younger, and more affluent), it should not be assumed that rural, older, less affluent people would have any particular resistance to these technologies were they available in the areas where they lived, but rather uptake was lower in areas of less population density because transport technology schemes were less commercially viable.

You've got a concentration effect because you've got younger people choosing to live in urban environments, so these services are more available to younger people so, wow! these services are used by younger people! So you've got to be wary of making too many assumptions because it's a lot about the demographics in the locations where the technologies are provided, then you assume that that's the demographic that will use them

There were views among stakeholders that aside from these overall trends for all future transport technologies, the characteristics of potential users of specific technologies varied by technology. For electric vehicles for example, it was suggested that uptake had been led by well-off middle-class males, as the cost of these vehicles was prohibitive for all but those on high incomes or who could obtain a company car, and men were more likely to make decisions about the purchase of a second car in a household, which an electric vehicle tended to be.

If it's a multi-car household that's preferable, because it allows you to blend a petrol or diesel car with an EV, so you have a petrol or diesel car as a fall-back.

Electric vehicle uptake was perceived to be lower among people living in rural areas, due to range limitations and the limited applicability of the technology in areas with challenging terrain such as hilly landscapes. Instead, electric vehicles were more likely to be used for shorter, regular, familiar journeys such as a commute in an urban or suburban location, to avoid the charging or range anxiety that may occur with longer journeys.

Users of lift sharing services tended to belong to particular groups to which the service was offered, for example, employees of a company that had set up a lift-sharing scheme for employees to use to commute to and from work. For car clubs on the other hand, a key demographic predictor of uptake was reported to be academic achievement at university level among users.

If you map out all the key mosaics across all the areas and you consider whether a car club would work in that area, the quickest, dirtiest way is to look at the academic achievement level of those people and it maps almost perfectly, at tertiary level of achievement...if there was one thing to do to increase uptake of shared mobility services, it's basically send more people to university

Non-users of technologies were generally those who faced barriers to using them, which are discussed in more detail in the next section.

Motivations and barriers

Barriers

For many future transport technologies, a lack of access to and availability of the technology was a key barrier - that is, technologies are not currently available in enough places to enough people. As privately-operated services, such as shared services and app-based minicab services, tend to be offered where demand is highest, those living outside of particular cities where the services operate are not able to use them.
We don't have a dense enough network of any form of transport, so bikeshare or public transport in general, and if it's not there then you can't use it

It was reported that if left to market forces, commercially-operated shared services such as bike sharing schemes and car clubs tend to be located in more affluent areas, as operators seek to avoid the higher risks of vandalism in more deprived areas. This therefore creates a barrier to using such schemes for people living in deprived areas.

One barrier to the uptake of all future transport technologies was the burden of ‘cognitive load’, that is, the task of getting to grips with using a new technology. It was explained that most people are satisfied with the mode of transport they currently use and would see no reason to re-evaluate their needs or invest time in learning how to use a new technology.

There's the cognitive load of finding out about these things, so unless you have some sort of mobility requirement in your life that isn't served with things as they are, why do you need to go and find out about something else? A lot of people are happy with car use and car ownership, so that's what they do.

The requirement to use the internet or a smart phone app to access many future transport technologies was seen as a barrier for those who are digitally or socio-economically excluded and therefore could not afford a smart phone. A bikeshare scheme set up in an area of deprivation in Glasgow which allowed users to load their account with cash rather than through an online transfer from a bank account, was cited as an example of an attempt to overcome this barrier of low income.

Cost was also considered to be a barrier to the uptake of electric vehicles, as they are currently expensive to buy. It was expected that until electric vehicles start trickling through into second hand market, uptake will remain low because of the barrier of cost. Furthermore, electric vehicle ownership currently requires the owner to have a drive or garage where they could position a charger, which excludes people who live in a property with no driveway or garage, which was estimated to comprise around 70% of households and may be more likely to include those on lower incomes. Other barriers to using electric vehicles include charging and range anxiety.

Resistance to the idea of using automated vehicles was considered to stem from values of control and autonomy, and concerns about data and cyber security. Barriers to the uptake of shared automated vehicles were thought to align with those to the use of shared traditional transport modes and included concerns around personal safety and a lack of independence, greater uncertainties around various aspects of travel, including the physical condition of a vehicle, and the value that people place on having their own private space in their car.

People still share ride-share as a bit risky, a bit unreliable, who knows who you're going to end up in a car with, is their car clean, does it smell? I think all these things are playing a part in people's decision making about whether to uptake these transport options or not

Barriers to uptake of MaaS were seen to include the lack of quality and capacity of current public transport systems, particularly outside of urban zones, that is required for an effective MaaS. Other pinch points for MaaS include, for example, concerns around a lack of parking at train stations. Furthermore, MaaS is perhaps less appealing to the many people who value familiarity of their mobility patterns over choice. There was a view that the vast majority of travel is local, familiar and predictable, and relatively few people have the hyper-mobility that would require the use of MaaS.

There is something fundamentally wrong with the way we think about behaviour that underpins MaaS, and that is the idea that people always want to make choices, that people always want the most efficient outcome. People value other considerations, and for many older people it's about not having to change bus and knowing what you're going to get, and not having to search for the best journey every time.

A barrier to the uptake of car clubs was believed to be that the business model of most car clubs was based on the service being used for short, regular journeys such as a commute to work, whereas in fact people tend to want to use car clubs for longer, incidental journeys in off peak times, such as day trips or weekends away. This made the service expensive to use for the longer journeys that people wanted to use them for, resulting in a mismatch between the service and people’s mobility needs.

There is a mismatch between what people would like to use them for, and the interests of the business models, and that's something across many of the newer technologies - how we can make the business models work in a way that actually meets the needs of users?

Key barriers to using ride pooling schemes, alongside concerns about personal safety, included a lack of convenience, as rides needed to be book on a ride-by-ride basis and transportation was typically not door-to-door.

It's not really convenient for people even if it saves them a couple of pounds...it's not a taxi service, it's not door to door, the driver will say I can pick you up around this area, and drop you off around this area some time... But also you probably have to book it on a ride by ride basis, which means you have to go on the website and find out what trips are available near your route, at the time you want to go, which creates a lot of transaction costs which puts them off if they have to do it every single time.

This lack of personalisation and flexibility could even act as a barrier to the uptake of a ride-share scheme by employees of the same company, as it was explained that even if they commuted to the same workplace, they might want to do different things on their journeys to and from work, such as go to the gym or take children to school.

People coming in and going back again from the same place at the same time is not that common anymore

Motivations

Key motivations to the uptake of future transport technologies were deemed to include cost savings and the ability of future technologies to meet people's mobility needs better than traditional transport. Some key motivations that helped people overcome barriers to using future transport technology were thought to include developments in the technology, social bonds between groups using shared services, and assurances around personal and data security.

Cost saving was considered a key driver of the use of technology such as app-based minicab services, car, bike and ride-sharing schemes and potentially shared automated vehicles if they were to reach a tipping point at which it became cheaper to use than public transport or private ownership of a car. It was explained that the entry price for shared schemes was low, compared with buying your own car or bike. Cost savings were also anticipated to motivate future take up of demand responsive services by local authorities, which could become a more cost-effective alternative to taxi services that they currently use to transport children to and from school.

Another key motivation was that some transport technologies could potentially meet the mobility needs of people whose needs were not currently being met by public transport services. For example, demand responsive services could enable people living in rural areas to commute to work more easily, or enable those in urban areas to travel on routes that better met their needs than those run by public transport operators.

Developments in technology that made it easier to use were identified as motivations. For example, e-bikes are being developed so that newer models are lighter and less cumbersome, making them more attractive to older users in particular. For MaaS, real time journey planning information on public transport was considered key to uptake and had already acted as an effective motivation in certain UK cities.

Motivations for using shared transport technologies, (that is, where multiple users use the same vehicle at the same time, such as ride-sharing schemes, rather than where multiple users use the same vehicle at different times, such as car clubs) were considered to be stronger if such schemes were set up for an already-established group, for example, employees of a company, students of a particular university, or people attending the same event or festival. In such instances, sharing was expected to enhance bonds between the group.

You are much more likely to have success with shared mobility if it's generated within a group of people who feel that they are part of a group, that they are together, rather than just saying, we've got a sharing app for the local authority, it's on the web, and you can use it. No, you've got to set up your tribe, your group. So working to build these tribes within work places, so that people felt they had the bonding within a group

Research with older people had similarly found that they were more positive about the idea of ride-sharing on an informal basis with people they already knew, perhaps because of greater levels of trust and therefore confidence in personal safety levels between members of a pre-existing group with a shared identity.

If the internet could be used to arrange lift sharing between people who already know each other, joining together people going to the same places, e.g. I'm driving into town now anyway, I can pick someone up - they would prefer that kind of thing than something more formalised

In an attempt to overcome the barrier of fears around personal safety in ride-share schemes, it was explained that some schemes allowed users to set up online profiles and receive ratings from people who had shared a lift with them. Furthermore, it was reported that some users had the perception that an information trail would exist through the website which they used to arrange the lift share, that could identify users in the event of any misdemeanour.

There are young people who are very comfortable with the idea of hopping in to the car with a stranger because ...they imagine if anything went wrong there would be an audit trail that would mean the miscreant would be caught, thereby reducing the risk of anything unpleasant happening, so it's not as risky as hitch-hiking.

A theme reported to have arisen from trials of automated vehicles was that people who are initially sceptical about the technology find that after experiencing it, their attitudes become more positive as they can better understand the potential benefits, such as enabling rural dwellers, older people, people with disabilities or blind people to gain access to a level of mobility they currently do not have. There was a view that even people who particularly enjoyed driving their own car would see the appeal of being able to use the technology on certain types of journey, such as long motorway journeys, on which they would rather be freed up to do other things.

I really love driving, but if I'm on motorways for instance, I might go down the M11, M25, M4, why on earth would I want to drive? I've spoken to real petrol heads who begrudgingly agree that if they could have a car which would do the hard work for them then they'd be very appreciative

Potential motivations to use a privately-owned automated vehicle were considered to be similar to those that currently motivate people to use taxis instead of public transport, for example they are tired, or have drunk alcohol, cannot find parking and do not want to be in a shared vehicle with people they do not know.

When you're talking to people who currently habitually use public transport, their reasons for using an autonomous vehicle are in line with their reasons for using a taxi, i.e. it's late, I don't want to get on a bus with some strange or difficult individual, I'd rather be in an enclosed space feeling safe.

Those people are not enthusiastic about sharing an automated vehicle with strangers, because that's what they want to get away from

There was a suggestion that to overcome the barrier of data security concerns around use of automated vehicles, a map of the data ecosystem, including details such as what data is recorded, who stores it and when, how they store it, and who has access to it, would help to allay people’s concerns.

For electric vehicles, key motivations to uptake were considered to include those that motivate early adopters in general, such as the image of being more technologically advanced, ahead of the curve and in line with global innovation. More recently, and perhaps broadening its appeal to a wider demographic, the Tesla brand’s marketing of their car as being aspirational; providing a slick, high-performance driving experience with features such as a quick pick-up, provided further motivations for uptake.

Incentives

Stakeholders referenced a range of types of incentive to increase uptake of future transport technologies. ‘Stick’ incentives such as the future ban on diesel cars, and currently, low emission and congestion charge zones, as well as parking pressures on employers, were considered to make carbon intensive transport modes more problematic and so act as incentives to the uptake of low-carbon transport technologies. Any future schemes of road pricing, parking charges and carbon taxation were expected to have a similar impact.

Among the ‘carrot’ type of incentives, it was explained that for electric vehicles, there were various government incentive schemes such as £3,500 off the price of a new vehicle, subsidies on the cost of fitting a charger in the home, no fuel duty on electricity and a lower rate of VAT. Additionally, electricity is offered free of charge in many locations including workplaces.

Additionally, marketing offers run by private operators were viewed as incentives, such as offers of money off an Uber ride, or incentives for car club members to recruit new members. Some lift share schemes offer incentives of a free or allocated parking space to users of the scheme. For bikeshare schemes, Cardiff University was highlighted as an example of an incentive scheme, as it has bought all students and staff 30 minutes of free riding time on their bike sharing scheme every day.

Impact on car use/current transport

There was a view that the impact of future transport technologies on traditional modes of transport is currently limited because future technologies are not widely accessible, and therefore can only be used by minorities.

However, notwithstanding the relatively small scale of uptake, technologies such as e-scooters, e-bikes, and bikeshare services were seen to have the potential to serve as effective ‘last mile’ transport modes, making it easier for people to use traditional public transport and use the new technologies for the first and/or last, short leg of their journey.

Nevertheless, there were also views that future transport technologies could be used instead of public transport, thus bringing levels of public transport use down. Furthermore, there was a perception that electric bikes and, although illegal, electric scooters, were, or had the potential to, be used as substitutes for walking and cycling rather than for using a car or public transport. Meanwhile, there were views that some car club users were using this service as a substitute for public transport rather than as a substitute for private ownership of a car.

In the US, research into the impact of Uber on other transport modes has reportedly suggested that Uber is competing with public transport, rather than feeding into or complimenting it by acting as a last mile service. That is, people are substituting public transport use with taking an Uber, potentially increasing congestion rather than enabling more sustainable mobility. There was a view that Uber and other transport technologies such as bikeshare schemes are similarly being used in place of traditional public transport modes in London, thereby reducing the critical mass of users of public transport, which in turn could threaten the longer-time viability of the public transport system.

Overall, there was a view that these technologies alone would not serve to reduce use of more carbon-intensive modes of transport unless they were part of a package that included other supportive policies.

It would be naive to think the roll-out of these technologies will in and of itself cause a reduction in reliance on carbon-intensive modes, additional policies need to be in place to facilitate this. These technologies need to be packaged as part of a wider range of expansion.

Evidence gaps

Key gaps in understanding around future transport technologies were considered to centre on explanatory insights into people's behaviour, values and motivations when choosing whether or not to use the technologies. For this reason, it was suggested that qualitative research was needed to provide such insight, rather than any quantitative surveys of the scale of uptake. Suggested areas for further exploration included:

- The societal impact of the technologies and subsequently, how society wants the technologies to develop in order to provide the maximum social benefits - there was a view that currently, development was focused on technological aspects rather than on how to make the technologies function most effectively for society. It was argued that there is a need to research and develop a vision for the future of a sustainable transport system, involving a broad range of stakeholders, including local authorities and transport experts as well as commercial operators. For example, there needs to be research into where people would want charging points to be located for electric vehicles; whether parking would be needed for automated vehicles and if so how this would work, how future transport technologies could help people make the journeys they want to make, but currently are unable to.

  There could be a future where transport system is seamless, another where different technologies compete with each other, so we should consider how to shape policy to ensure it runs in the way we want it to in the future

  We need a visioning exercise to work out what we want from our towns and our cities and our mobility and work back from that, so how can these technologies help us to achieve what we want

  This could also include an exploration of people's motivations, attitudes and value systems around mobility, including what they value about the modes they currently use, and how this impacts on their level of interest in and uptake of future transport technologies, particularly around using shared services.

We find [it] a bit frustrating...that a lot of the research in the area is set up as if it's market research. To whom should we market or who do we need to convince because they're not enthusiastic? In a sense, that should be a downstream activity as opposed to really understanding what people want to get out of their transport system

As part of this visioning exercise, it was suggested that the impacts on those who will not use these transport technologies needs to be considered. For example, if it becomes more difficult or expensive to use diesel cars, those living in rural areas who are unlikely to have access to future transport technologies for a long time will need to be supported to ensure they are not disadvantaged.

- Whether these technologies all compete for the same users, or whether different technologies appeal to different groups - if it is the former, it could be that they hold niche appeal and uptake will be limited.

  So if you provide one they'll go with that, if you provide another they'll go with that. If you provide them all are you essentially cutting the market into pieces, because it's the same people chasing the same things

  Linked to this, research was suggested into how to widen the market for each technology to make them more appealing to a wider segment of the population beyond the current niche market of early adopters.

- Insight into the uptake of certain technologies that are not yet available on a widespread basis - for example, MaaS, higher-level automated vehicles and flexible, demand responsive services that are internet based are still rare in the UK, so that any research into uptake is still hypothetical as it is based on what people think they might do rather than what they would actually do. This was noted as a particular challenge in fields where technology is advancing so rapidly that research was struggling to keep up with the changes in technology. For MaaS, it was felt that there needs to be more research in to people’s actual behaviour based on real experience of using the technology, rather than asking them theoretically what they think they would do if they could use it. This would require structured pilot trials and evaluations of the implementation of a MaaS. For example, research into how people could travel in a particular city on end-to-end journeys without using a car, using real case studies.

  We've got loads of evidence about what people think, what we don't have is much evidence about what people do. My plea would be can we stop asking people what they think, and start doing some pilot implementations and see what happens?

- How to replicate best practice across the UK - this includes learning from successful schemes such as car clubs and considering what works in geographical areas outside of London.

  We don't understand well enough what transport interventions work when you don't have that critical mass that you have in London but not other UK cities

- Consideration of the type of business model that we want to see in the UK for future mobility technologies - it was suggested that primary benefits of technologies could be societal rather than fiscal, for example, they could help people access health care services, education or employment more easily, rather than bringing direct profit to the operator or provider of the service.

Existing and forthcoming research

Although there was reported to be an extensive body of literature on technologies that are already being used on relatively wide scales, such as electric vehicles and sharing schemes, a note of caution was raised around studies that have asked people for their imagined or hypothetical response to a technology that they have not had the opportunity to use yet, such as automated vehicles and MaaS. Nevertheless, there are various pieces of research into people's propensity to at least consider using such technologies.

For research into uptake of car clubs and bikeshare schemes, Como UK was cited as having produced the most well-known body of research, particularly its annual survey of users of the car clubs and bikeshare schemes for which it is an umbrella organisation. Lift Share and Zipcar were also reported to have carried out research into users of their schemes, and Arriva Click were reported to have collected data on the users of the app-based demand responsive services they have operated. Further, Transport Systems Catapult's *Traveller needs and UK Capability Study* identified five types of user, each of which was deemed to have different likelihoods of taking up new types of mobility technology. This report also explored pinch points when using technologies.

Trials of certain technologies were also expected to provide useful insight into uptake. This included the WHIM trial of a MaaS in the West Midlands that was launched in 2018, and trials of electric bikes by a sample of older people run by the Cycleboom project at Oxford Brookes University.

Forthcoming research that was considered relevant to the issue of uptake of these technologies included a piece of research being carried out at Loughborough University into where transport infrastructure should be placed in order to be optimally utilised. This includes looking at where preferred drop off and pick up locations are for bike sharing schemes, to enable them to be used for as many trips as possible, and where electric vehicle charging points should be located so that they generate the most benefit. Further, an upcoming briefing in December 2019 on the Triangulum Project by Manchester City Council was expected to provide some insights into energy, transport and smart technology and how it can be applied in the city context.

Appendix G. Data extraction template

Table G.1 shows the format of the data extraction template. This was an excel document and the version used for data extraction had separate columns for different research questions and types of information, e.g. measurement used, quantitative data and narrative data. Table G.2 shows the quality assessment score criteria.

Table G.1 Format of data extraction template

Study description

Reference ID	*Lead author_year (copy filename)*
Researcher	*Initials*
Title	*Study title*
Authors	*Lead author*
Publication date	*Year*

Scope of study

Summary of study	*Brief summary of study, including aims and research questions*
Location	*Country, region, town/city*
Transport types	*List transport type and definition (e.g. what's included).* ** Mobility as a service (MaaS)* ** Connected/autonomous vehicles* ** Shared transport* ** Dynamic/flexible transport* ** App-based minicabs* ** Electric vehicles* ** Electric bicycles* ** Electric scooters*
Population	*Describe any population groups the study focuses on, e.g. young adults, over 65s, living in London, electric vehicle users in Birmingham*

Methods	*Describe methods used in research with basic info, e.g. sampling approach, inclusion criteria and number of respondents. Please include page/table number.*
Outcome measures	*Describe outcome measures used:* **Consumer uptake (what characteristics are described)* **Barriers, motivations and motivations to uptake* **Effectiveness of incentives* **Impact on other forms of transport* **Evidence gaps*

Research questions

1.1. Consumer characteristics
1.1 What are the characteristics of users - <u>people</u> who use these transport technologies? What are the characteristics of non-users? *Describe characteristics covered in outcomes. Non-exhaustive list of examples:* **Demographic, e.g. sex, age, income, employment, household type* **Psychographic, e.g. attitudes to transport, environmental beliefs, attitudes to car ownership/symbolism, attitudes to technology, e.g. early adopters* **Behavioural, e.g. travel behaviour (regular commuters, occasional travellers, non/drivers, bus users)* **Geographic, e.g. urban/rural, location (country/region/town)* Information collected on relevant measures, quantitative and narrative data
1.2 Journey characteristics
1.2 What are the characteristics of journeys? *Describe journey characteristics covered in outcomes. Non-exhaustive list of examples:* **journey type or purpose, e.g. regular commute, one off holiday, regular trip to local town/hospital (e.g. demand responsive transport), school run* **who travelling with* **distance, e.g. long/short distance*

**location, e.g. rural, urban, suburban, cross country* Information collected on relevant measures, quantitative and narrative data
1.3 Motivations and barriers
1.3 What are the barriers to using transport type? What are the motivations/enablers? *Describe the motivations and barriers reported* Information collected on relevant measures, quantitative and narrative data
2.1 Incentives
2.1 What incentives have been used to encourage transport uptake? How effective are they, for which groups? *Describe incentives covered in study. By incentives we mean things deliberately put in place, e.g. by government, local authorities, transport providers, to encourage use.* Information collected on relevant measures, quantitative and narrative data
2.2 Impact
2.2 What is the potential impact of these new technologies on traditional modes (car, public transport)? For which consumers? *Describe what impacts are covered, e.g. road use, rail use, use/ownership of petrol/diesel cars* Information collected on relevant measures, quantitative and narrative data
3.1 Evidence Gaps

3.1 What are the evidence gaps or areas of future development mentioned? *Describe evidence gaps or areas of future research mentioned? Includes details of what the gaps are: transport type, particular consumers, locations, journey types, overcoming barriers* Information collected on relevant measures, quantitative and narrative data

Table G.2 Quality and relevance assessment scores attributed to each of the criteria

The quality and relevant assessment tool we used was adapted from the weight of evidence tool (for more information see: https://efsa.onlinelibrary.wiley.com/doi/10.2903/j.efsa.2017.4971).

Research aim	**How clearly is the research aim stated?**	High=2, medium=1, low=0
Inclusion criteria	**How clearly does the study set out its inclusion criteria?** *- [IF REVIEW:] Inclusion criteria is a list of criteria that evidence will be screened against to determine eligibility for being included in the review* **-***Does it state and define the topic areas, populations, publication type/date, type of study design of interest to the research?*	High=2, medium=1, low=0
Research questions	**How well does the article address the research questions outlined?** *-How well is it written? E.g. does it have an academic/formal tone?* *Is it clear? Are there spelling mistakes? Is it peer-reviewed?*	High=2, medium=1, low=0
Methodology	**How well does approach fit the research questions?** *How well does approach allow us to answer research questions?*	High=2, medium=1, low=0

Methodology description	**How well does the study describe its methodology?** *-Do the research methods map onto the aims and objectives?* *- Are the methods and the rationale discussed? E.g. quantitative methods are used, is this justified?* *- Is there a section on sampling and ethics?* *-Are the limitations of the respective approaches discussed?*	High=2, medium=1, low=0
Relevance to our research	**To what extent does the question address our research questions?** *E.g. does it speak directly to one or more research questions or only indirectly?*	High=2, medium=1, low=0
Total score	**Total/Overall score:** *When deciding final score, consider that each area is weighted equally*	High, medium or low quality

Appendix H. References selected for data extraction: Summary

Lead author	Year	Title	Transport type	Method	Quality/relevance
Anable	2011	Consumer segmentation and demographic patterns	Electric vehicles	Project report. Two stage web survey of electric vehicle owners in Great Britain.	10
Anable	2014	Consumer responses to electric vehicles	Electric vehicles	Systematic literature review of evidence of electric vehicle uptake. International, including UK	10
Angeloudis	2019	Review of the UK passenger road transport network	MaaS, AVs, shared transport	Evidence review of UK passenger and transport network.	10
Axsen	2019	The role of users in electric, shared and automated mobility	MaaS, AVs, shared transport, app-based taxis, electric vehicles	Review of insights from special edition 19 articles (international, including UK).	9
Beard	2019	Consumer uptake trial report: Mainstream consumers' attitudes and willingness to adopt BEVs and PHEVs.	Electric vehicles	Project report: 200 drivers recruited to trial electric vehicles over several days. Research covered self-reported attitudes and willingness to adopt EV before and after trials and included choice experiment after use on importance of attributes.	9
Behrendt	2016	Why cycling matters for Smart Cities, Internet of Bicycles for Intelligent Transport	MaaS	Trials of electric bicycles with smart monitoring system, involving 80 commuters in Brighton. Information collected through post trial interviews, focus groups and surveys. Explores 'smart velomobility', networked practice and technologies.	10
Brook Lyndhurst	2015	Uptake of Ultra Low Emission Vehicles in the UK	Electric vehicles	Rapid Evidence Assessment, United Kingdom.	8

Lead author	Year	Title	Transport type	Method	Quality
Catapult	2015b	IM traveller needs and UK capability Study: Supporting the realisation of intelligent Mobility in the UK	MaaS, AVs, shared transport	Segmentation of population by demographic, attitudes and behavioural characteristics. Survey (n=10,000), expert (n=100) and company (n=50) interviews.	10
Cavoli	2017	Social and behavioural questions associated with automated vehicles: A literature review	AVs	Literature review of published and grey literature, international including UK.	5
Clark	2016	Introducing driverless cars to UK roads	AVs	Literature review of academic and grey literature. International, including UK.	7
Community transport association	2017	The future of demand responsive transport	MaaS, shared transport, demand responsive transport	Working group, 'listening days' with stakeholders, including community, consultants, academics, charities. Pro-social transport event	4
Bikeplus Carplus	2018d	Findings and recommendations from eleven shared bike schemes	Electric bikes	Project report. First annual review of eleven shared electric bike schemes, based on survey and trip (GPS) data, one off and regular users.	8
Department for Transport	2019	Transport and technology: public attitudes tracker: Wave 3	MaaS, shared transport, app based taxis, autonomous vehicles	Face to face survey of 3,500 adults aged 16 and over and living in England. Questions included in face to face Omnibus survey.	9
Enoch	2015	How a rapid modal convergence into a universal automated taxi service could be the future for local passenger transport	AVs	Concept paper, involving literature review and discussion	2
Enoch	2018	Mobility as a service (MaaS) in the UK: change and its implications	MaaS, AVs, shared transport, app-based taxis	Evidence review	2

Lead author	Year	Title	Transport type	Method	Quality
Government Office for Science	2019a	A time of unprecedented change in the transport system	Electric vehicles	Explored four scenarios for future transport and examined current and past trends to highlight 10 key areas.	10
Government Office for Science	2019b	Decision making in the UK transport system	MaaS, shared for, demand responsive transport	Evidence review, with a focus on consumer decision making	10
Nur / The Institute of Engineering and Technology	2019	Could mobility as a service solve our transport problems? Developing a better understanding of MaaS, its evolutionary path, benefits, unintended consequences and deployment challenges	Electric vehicles	Implementation scenarios. In depth interviews with passengers of ten MaaS systems. International, including Manchester.	5
International Transport Forum	2019	Regulating app-based mobility services	MaaS, shared transport, demand responsive transport	Think tank annual report around emerging transport technologies and different regulatory response. Literature reviews and round table discussions.	6
Institute for Public Policy Research	2017	Crossroads: Choosing a future for London's transport in the digital age	MaaS, AVs, shared transport, demand responsive transport, app-based taxis	Evidence synthesis. Research - workshops, surveys, interviews with key stakeholders from public, private and third sectors	10
Kamargianni	2015	Feasibility study for Mobility as a Service concept in London	MaaS, shared transport, app-based taxis, electric vehicles	Review, concept and feasibility study of MaaS in London - assessment with operational, technical and economic criteria, plus SWOT analysis of market	9

Lead author	Year	Title	Transport type	Method	Quality
Le Vine	2015	A new approach to predict the market and impact of round-trip and point-to-point car sharing systems: Case study in London	Shared transport	Qualitative interviews and quantitative modelling to understand size of car share market and potential impact on other forms of transport. Covered car owners, drivers and car share subscribers in London.	11
Le VIne	2019	The impact of free-floating carsharing on car ownership: Early stage findings from London	Shared transport	Web survey of around 300 customers of a free-floating car scheme based in London	10
Matyas and Kamargianni	2018	Exploring Individual Preferences for Mobility as a Service Plans: A Mixed methods approach	MaaS, shared transport, app-based taxis	Online survey (n=1138) and in-depth interviews (n=30) in London to explore preference for different MaaS ticketing and transport combinations	8
Marshall (Ipsos MORI)	2019	Shared mobility	Shared transport, Demand responsive transport	Focus groups and in-depth telephone with regular transport users in London, and shared transport users in UK cities. Explored barriers, motivations and incentives to uptake.	10
Mounce	2018	Modelling, Aberdeenshire and Morayshire	Demand responsive transport	Project report. Modelling uptake of demand responsive transport	6
McCool	2019	AV public acceptability dialogue: Engagement report	AVs	Workshops and post engagement telephone interview with around 150 people (general public) in Wales, Scotland, England	2
Merat	2017	Human factors, user requirements and user acceptance of ride-sharing in automated vehicles	AVs	Literature review: Summary of key findings from several recent surveys	4
Merge Greenwich	2018b	One in three London Car Journeys could be in an Autonomous vehicle by 2025	AVs	Customer research with potential users: Online survey and face to face focus groups with potential users of AV, for individual trips and ride-pool	10

Lead author	Year	Title	Transport type	Method	Quality
Nikitas	2017	How can Autonomous and Connected vehicles, Electromobility, BRT, Hyperloop, Shared Use Mobility and Mobility-as-a-Service shape transport futures for the context of smart cities?	MaaS, AVs, shared transport, electric vehicles	Literature review covering a range of transport technologies. Wide scope, including exploring the future landscape of travel, barriers to use.	4
Ognissanto (TRL)	2018	Innovative active travel solutions and their evaluation	Electric bikes	Small scale trial of e-bikes with feedback gathered through survey and open questions. Very small test of micro-scooters, including an e-scooter.	8
Wang	2015	Exploring the propensity to travel by demand responsive transport in the rural area of Lincolnshire in England	Demand responsive transport	Survey of 432 users demand responsive transport in Lincolnshire. Explores individual factors and models likelihood of take up.	10
Wang	2014	Multilevel modelling of demand responsive transport (DRT) trips in Greater Manchester based on area-wide socioeconomic data	Demand responsive transport	Quantitative, multi-level modelling of demand responsive transport in Greater Manchester	12