# User Decision-Making in Transitions to Electrified, Autonomous, Shared or Reduced Mobility

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**Abstract**

Mobility affords a range of benefits, but there are environmental, social and economic problems associated with current transport systems. Innovations to address these issues include novel technologies (e.g., electric and autonomous vehicles; EVs, AVs), and new business models and social practices (e.g., shared mobility). Yet, far more attention by policy-makers and researchers has been paid to the technical aspects of a low-carbon mobility transition than to social or psychological aspects, or the role of the user. In this paper, we integrate insights from the multi-level perspective on transitions and socio-psychological literature and draw on transport expert interview (N=11) data, to examine (a) what influences current attitudes and behaviours in respect of EVs and AVs, and shared mobility, and (b) how this may change in the years to come. We argue that technological change may be most compatible with the transport regime (dominated by personal car-based mobility) but potentially affords a narrower range of sustainability benefits, while mobility substitution (e.g., reducing the need to travel through tele- working or -shopping) may be most challenging for both policy-makers and publics, while potentially addressing a wider range of sustainability problems associated with the transport regime. Shared mobility options sit somewhere in between and challenge certain aspects of the regime (e.g., status associated with car ownership) while offering certain environmental, social and economic benefits. For all three areas of innovation, policy interventions need to address the needs, preferences, experiences and identities of users if they are to be effective and sustainable.

**Keywords**

Low-carbon mobility, transition, multi-level perspective, psychology, decision-making

**Highlights**

- We provide a psychologically-informed discussion of the transition to low-carbon mobility.
- Our analysis highlights nuances in the interaction between individuals and infrastructures, and how 'lock-in' is experienced in different ways.
- Users fulfil important social as well as economic functions in innovation processes.
- Social and psychological factors (identity, emotions, etc.), as well as physical environment and infrastructures, constrain and foster innovation.

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# 1 Introduction

The transport sector, and particularly road transport, is experiencing significant change. After decades of the internal combustion engine and personal mobility dominating road transport, this dominance is no longer a certainty. Mobility affords a range of societal and economic benefits, but problems with current transport systems include greenhouse gas emissions and air pollution, social inequality, congestion, collisions (often caused by human error), and obesity (e.g., Barr, 2018). Indeed, in the UK, greenhouse gas emissions are rising faster in the transport domain than in any other sector (BEIS, 2017). Innovations to address these issues include novel technologies (e.g., electric and autonomous vehicles), and new business models and social practices (e.g., shared mobility). Yet, far more attention by policy-makers and researchers has been paid to the technical aspects of a low-carbon mobility transition than to social or psychological aspects or indeed to the role of the user (Barr, 2018). The innovation literature highlights the critical role of users as potential drivers of, or barriers to, successful change (Geels, 2002); users may play active or passive roles in such change, and shape transition outcomes in profound ways (Nye et al., 2010).

The current paper brings together the macro-level view of transitions with micro-level insights from psychology and allied disciplines to examine drivers and barriers to innovation in mobility. As such, we seek to address the under-theorisation of users and their behaviours in understanding low-carbon mobility transitions. Specifically, we use the Multi-Level Perspective (MLP; Geels & Schot, 2007) as a framework to discuss the socio-technical aspects of the transition to low-carbon mobility; while the roles of transport users are explored from a socio-psychological perspective. Innovations in domestic, land-based transport modes for non-commercial use are our primary focus with implications for transitioning to low-carbon mobility discussed. This focus enables consideration of the main policy innovations that are intended to disrupt current individual mobility behaviour (UK Government, 2017); although we recognise that innovation in areas such as freight and aviation is also critical for achieving a more general low-carbon mobility transition. Using a narrative review of the socio-psychological literature and interviews with transport experts, this paper examines socio-psychological factors working to constrain or drive innovation in respect of electric vehicles (EVs[1]), connected autonomous vehicles (CAVs[2]), and shared transport[3]. Specifically, we address the following research questions:

- What role do socio-psychological factors play in transitioning the transport regime to low-carbon mobility?
- How do (or might) users act as facilitators of, and barriers to, radical innovation in mobility systems?
- What opportunities exist, or could emerge, to align policy delivery with users' preferences and behaviours in order to promote low-carbon mobility options?

Before providing results from our review and interviews, we first outline the MLP and socio-psychological theories we are drawing on.

### *1.1 Multi-Level Perspective and low-carbon transport*

The MLP has increasingly been used to conceptualise and analyse processes of radical innovation ('transition') within social systems (e.g., the transport system; Geels, 2011;

[1] We use the term EVs to refer to battery electric vehicles (not hybrids or plug-in hybrids or other electrically powered personal transport, such as e-bikes or e-scooters).
[2] We use the terms AVs or CAVs to refer to vehicles with a high or full degree of automation (i.e., the automated driving system monitors the driving environment), specifically Level 3 (Conditional Automation), Level 4 (High Automation) or Level 5 (Full Automation; SAE, 2016).
[3] Shared mobility involves the sharing of assets synchronously (e.g. car-pooling) or asynchronously (e.g. sharing club membership), a distinction which is critical for space efficiency and emissions levels (Parkhurst & Seedhouse, 2019). Shared mobility may be associated with increased multimodality – whether within a specific trip or across a mobility lifestyle and is facilitated through mobile digital technologies which enable enhanced dynamic travel information and sometimes integrated ticketing. A specific form of shared and multimodal travel behaviour is Mobility-as-a-Service (MaaS), an emerging concept that bundles access to different transport modes in a fixed-price contract, with similarities for those in the mobile telephony sector. Shared mobility also includes novel options, such as 'ride-sourcing' (Rayle et al., 2016) and dynamic car-pooling, as well as the more traditional options of taxis and public transport. We focus in particular in this paper on the more innovative elements of shared mobility.

Whitmarsh, 2012). The MLP is so called because it identifies three levels within societal systems: niches, in which radical innovations emerge; the regime, which comprises dominant institutions and technologies; and the landscape, which represents macro-level trends and contextual drivers and barriers to change. The main dynamics of change occur within and between the regime and niche levels, which may interact synergistically or antagonistically (Geels & Schot, 2007). Typically, change at the regime level is incremental due to sunk investments, vested interests, habits, bureaucracy and other factors which afford stability but equally constrain flexibility and opportunities for radical change. At the niche level, on the other hand, actors are much less constrained by dominant institutions and the status quo, and can experiment with radical alternatives to solve societal problems and address pressures at the landscape level. The landscape is understood to be the environmental, socio-economic and cultural context in which actors and institutions are situated, the contours of which make certain trajectories more likely than others (Smith et al., 2005).

The MLP has been a useful tool for analysing transitions in a more systemic and interdisciplinary way than previously; yet arguably its focus on technological innovation means it has suffered from an under-theorising of how behavioural–institutional change might occur (Whitmarsh, 2012). Indeed, the diverse roles and actions of users have been under-explored, with a focus more on the 'consumer' role than other roles (e.g., parent, worker, citizen; Murtagh et al., 2012) and there has been little attention to how perceptions and behaviours are shaped and evolve (Nye et al., 2010). Here, we seek to address this limitation by integrating the MLP and transitions literature with literatures on decision-making and user perspectives on transport.

Since the 1950s, the personal internal combustion engine vehicle (ICEV) has increasingly become the dominant transport mode in developed countries, due in part to a process of changing transport mode choice, but more as a result of personal mobility, measured in terms of distance travelled, rising significantly (Urry, 2004; Geels, 2018). The role of the private car in facilitating this growth has been central. For instance, in the UK the majority of travel is now undertaken by car (93% of the road distance travelled or 64% of trips made in 2015; Figure 1) (TSGB, 2017). At the same time, cycling has declined substantially (from 13% of distance travelled by road in 1952 to less than 1% in 2015). Whilst rail travel has doubled since 1994, it remains a minority mode as a share of distance (10% of distance travelled by road, rail and domestic flights in 2015) (TSGB, 2017). It is important to note, however, that car use is not equally dominant in all income groups. In the UK, for instance, those in the lowest quintile (20%) of household income have the highest frequency of walking, cycling and bus use, and lowest frequency of car use as a driver, of all income groups (Figure 2).

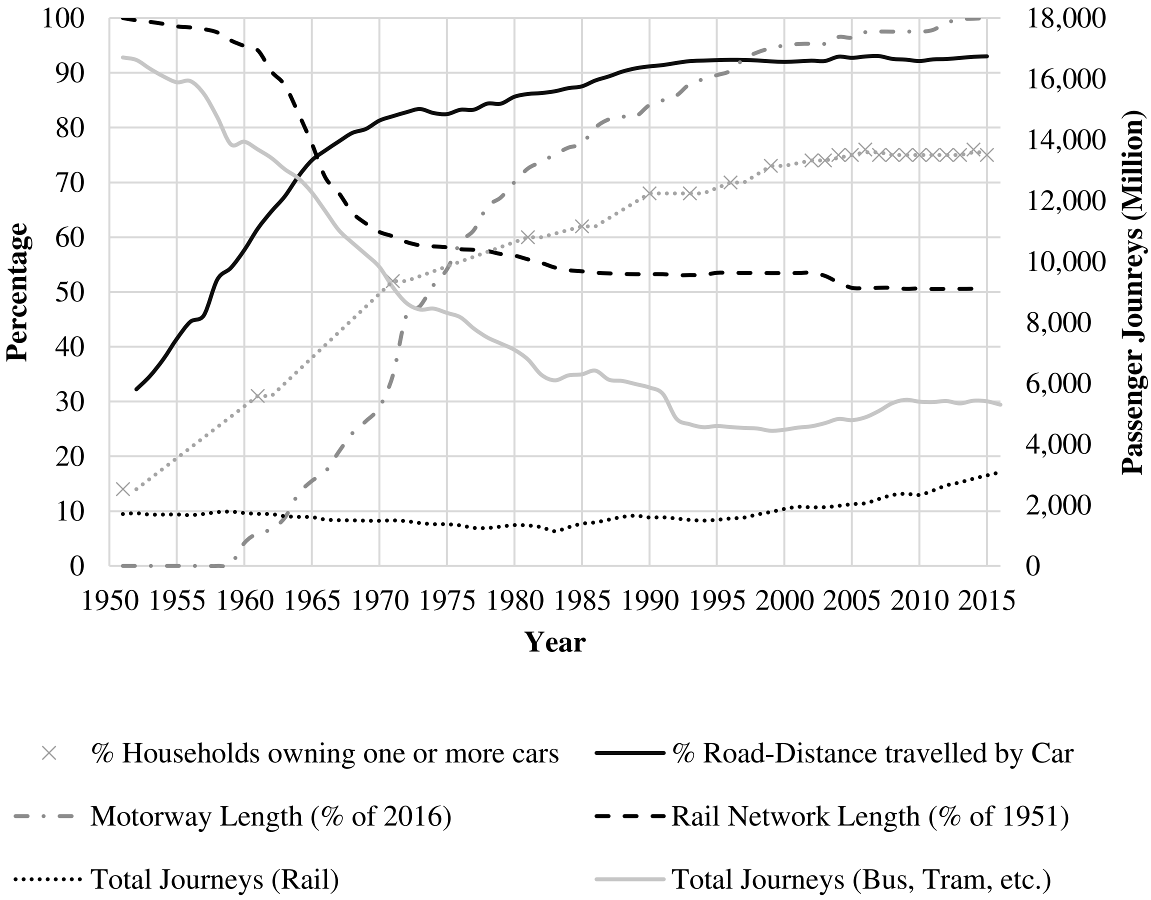



*Figure 1. Trends in car ownership and modal choice in the UK (1950-2015; source: DfT, 2016)*

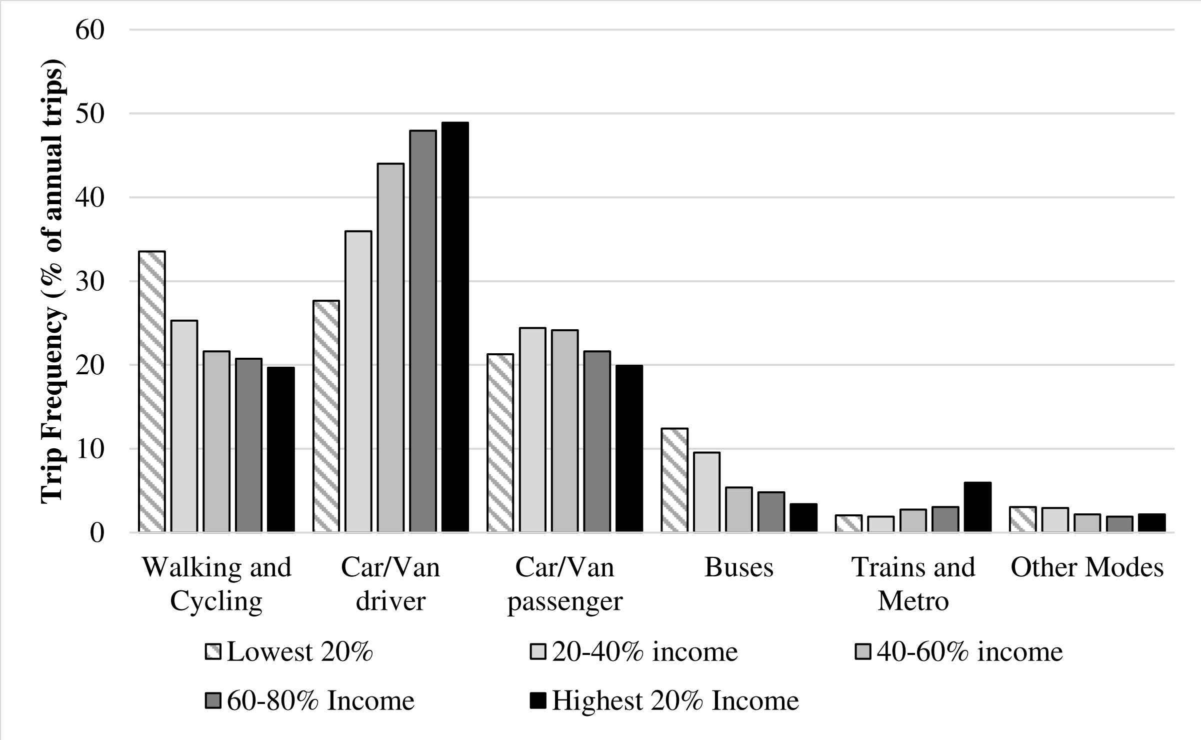



*Figure 2. Transport modal split by income group in the UK (source: DfT, 2016)*

In many developed countries, such as the UK and US, the current mobility regime can be defined in terms of 'automobility' – that is dominance of privately-owned cars (Geels, 2018; Urry, 2004). More specifically, these privately-owned cars are typically ICEVs; hence our definition of mobility regime captures vehicle/fuel technology and ownership, along with associated socio-psychological and structural elements (e.g., personal autonomy, roads, spatial planning; Sovacool, 2017). This current regime of personal ICEVs dominating transport decision-making has a number of harmful implications for the natural environment and for health (Sims et al. 2014). As such, the economic, ecological and cultural landscape in which the regime is operating is changing and the regime is under pressure. Vehicle use is a large contributor to climate change. It is estimated that the transportation sector contributes 14% to global greenhouse emissions, but a greater share in the more industrialised, transport-intense economies: 25% in the EU and 27% in the US: of these totals, 73% and 85% respectively arise from road transport (Greene & Parkhurst, 2017). In addition, the extraction of oil needed to fuel ICEVs is encouraging the destruction of natural habitats and displacement of indigenous populations (Finer et al., 2008). At the same time, motor vehicle traffic has been identified as the single most important source of health-threatening air pollution in many of the world's megacities and an important source in the others (Mage et al., 1996). In the UK, for example, the Royal College of Physicians (2016) concluded that around 40,000 premature deaths per annum were attributable to exposure to outdoor air pollution, with road transport being the key source of emissions to address. Social problems associated with ICEV dominance include collisions, obesity, and inequality in access (Lucas, 2009; see also Figure 2), while economic costs of congestion and land-use for road infrastructure are also significant.

Alongside these ecological and socio-economic landscape changes, there are also noteworthy indications of a change in the cultural landscape. Various transport statistics in the UK (Chatterjee et al., 2018), as well as in some EU countries, such as Sweden and the Netherlands (Focas & Christidis, 2017) indicate that factors such as license-holding, car-ownership and aspects of car-use that, historically, have been increasing steadily for decades, could be reaching their 'peak', plateauing or even beginning to decline. These trends are especially evident amongst young adults (Tilley & Houston, 2016). This phenomenon has been termed 'peak car', although whether it is actually a peak or a pause is debated (Focas & Christidis, 2017). The UK Department for Transport (DfT, 2018), for example, forecasts through seven scenarios that road traffic will rise between 17% and 51% from 2015 to 2050, with factors such as population growth and – notably for the context of the current paper – the lower assumed cost of electric car use, being two of the principal promotors of growth. At the same time, however, fewer younger people are qualified drivers compared to previous generations (Kuhnimhof, et al., 2012; Tilley & Houston, 2016). In the UK, since the 1990s, 40-69 year-olds have maintained a consistent level of driving-licence holding, whereas, since peaking in the 1990s, licence holding of 16-19 and 20-29 year-olds has declined, this latter trend arising from declining license-holding amongst younger men (DfT, 2016). Furthermore, in the UK, early-life transport behaviour is sustained into later-life (e.g., lower car usage of 17-29 year olds during the 1990s is maintained in the present day) and those who start to drive later in life will subsequently drive less (Chatterjee et al. 2018). Whilst the ‘peak car’ phenomenon is complex, researchers appear broadly divided between those who attribute changes to extensions of historical trends (e.g., fuel-prices, real-income, urbanisation and embedded car-culture: e.g., Wells & Xenias, 2015; Bastian et al., 2016; Stapleton et al., 2017) and those that identify an emerging shift away from car-dependency (e.g. Metz, 2012; Lyons, 2015). It may be that both perspectives are relevant: there may be a polarisation of mobility styles in the future, low car dependence as-a-choice on the rise, but those who are car dependent exhibiting even greater car-based mobility.

Other aspects of the transport landscape are also changing, either exacerbating or resulting from societal megatrends. For instance, population ageing is one of the causes of UK population growth identified above, and was experienced first in the wealthiest, most industrialised states, but is now a global trend. For example, individuals aged 65-years or above constituted 18% of the UK population in 2017, forecast to increase to 24% by 2036 (ONS, 2017). Many European countries (e.g., Germany, Italy) are also projected to have markedly higher percentages of older adults by 2035 (ONS, 2017). Furthermore, the industrialising states will in fact overtake the industrialised states in their ageing rates in forthcoming decades, so that the number of people aged 60+ will double from 901 million in 2015 to 2.1 billion by 2050 (United Nations, 2015). There is evidence that as individuals live longer, they continue to drive and use public transport (Rosenbloom, 2010). If this trend continues, there will be implications for transport demand and its associated impacts (traffic, emissions, road-safety, etc.; Clarke et al., 2010).

Alongside demographic change, technological developments, notably in information communication technologies (ICT), are another significant landscape-level trend intersecting with mobility systems to significantly restructure travel choices, both in terms of vehicle type (e.g., CAVs) and modal options (e.g., synchronously and asynchronously shared mobility).

As outlined, within the MLP framework, the changing landscape and pressures on the regime open up opportunities for the expansion of niche innovations. Whilst developments in ICEV technology have led to incremental improvements in energy efficiency and carbon dioxide emissions (Kobayashi et al., 2009) more radical, low-carbon niche innovations are being developed in mobility (Sarasini & Linder, 2018). According to Nykvist and Whitmarsh (2008), these niche innovations can be grouped into three broad, qualitatively different approaches to sustainable mobility: (a) The *radical vehicle technology* category captures transport technologies which are disruptive to the transport system, either in the market structure, product, or consumer behaviour; (b) The *product-to-service shift* category captures cultural, institutional and behavioural changes that enable more efficient use of resources by focusing on mobility services and public transport; and (c) The *mobility substitution* category captures overall lower transport demand and resource consumption. Across these three areas, advances in the capabilities and availability of ICT (as well as other technologies, e.g., batteries) are key elements of the innovation observed (Nykvist & Whitmarsh, 2008; Andwari et al., 2017). However, each innovation faces different barriers and facilitators to achieving adoption and utilisation, which will impact on the extent to which it is able to disrupt the regime. These barriers and facilitators have so far been explored more from a technical or socio-economic perspective than from a psychological one, but there is much insight that psychological literatures can bring to understanding transitions (Whitmarsh, 2012).

### *1.2 Psychological perspectives on low-carbon mobility transitions*

Contrary to strawperson depictions of psychology (e.g., Shove, 2010), many psychological models of behaviour do acknowledge that behaviour is shaped both by ‘internal’ factors (e.g., attitudes, knowledge) and ‘external’ factors (e.g., location, social norms) that enable and inhibit choices. Indeed, classic models in psychology, such as Lewin's field theory (1951), state that behaviour is a function of person and environment; and more recent and widely-applied models such as the Theory of Planned Behaviour (Ajzen, 1991) posit that behaviour is an outcome of attitudinal, social and structural factors (cf. Stern, 2000). Certainly, some psychological theories, such as the Value-Belief-Norm model (Stern et al., 1998) which has been very influential in environmental psychology, do not endeavour to explain 'external' factors, instead focussing on internal processes or on behaviours that may be relatively unconstrained by institutions or infrastructures (Sovacool & Hess, 2017). Nevertheless, to understand behaviour and decision-making in relation to mobility requires attention not only to norms and meanings, but also to structures and relations that prescribe and proscribe travel (Anable et al., 2006; Axsen & Kurani, 2012). As such, we aim to include in this paper key factors that shape mobility decision-making, both internal and external, some of which may be within the scope of other disciplines (e.g., economics, sociology, planning) as well as psychology. At the same time, we acknowledge critiques of psychological perspectives as methodologically individualistic and traditionally incremental in focus (Barr, 2018) and seek to draw selectively on insights from other disciplines to address the need for more systemic and radical innovation in mobility. As such, our review is not intended to be aligned with a particular theory, but instead to draw on predominantly psychological insights on user behaviour and decision-making in relation to low-carbon mobility innovations (cf. work by Sovacool (2017, 2018).

## 2 Method

The method drew upon on multiple sources of evidence to address our research questions. Our primary evidence base is the peer-reviewed academic literature elicited through bibliographic searches and a call for evidence, complemented by expert interviews. This mixed approach is particularly appropriate for the context of emerging transport technologies and modes, in which the relevant literature arose from several disciplines, many of the ideas are nascent and the field is rapidly evolving; triangulation can both provide validation and expand understanding (Olsen et al., 2004).

### *2.1 Narrative review*

A review of the socio-psychological literature relating to EVs, CAVs, and shared transport was undertaken. Keywords for each transport technology or service were identified including: "electric vehicle"; "autonomous vehicle"; "vehicle sharing" or "shared vehicles"; "ridesharing" or "carpooling"; "shared bikes" or "bike sharing"; and "mobility as a service". In each instance of "vehicle", "car" was also used. Keywords that are conceptually similar to "acceptance" were then identified creating a search string of "acceptance OR adoption OR perception OR attitude OR intention OR behaviour". This search string, in conjunction with each technology or service terms in turn, was entered into the journal database, Scopus. There was no set limit on the publication year. Studies were selected based on their relevance to the research questions. To endeavour to address publication bias and to maximise identification of relevant literature, a call for evidence was used. The call was distributed through researchers' contacts and existing, related email lists. The call was sent on the 1st November, 2017 to pre-existing email lists of transport researchers. The level of response was low in number (N=4) and identified only published research. The suggested literature was incorporated into the results where appropriate. Although primarily peer-reviewed literature was included, no formal assessment of the quality of the evidence was made although we note the weaknesses and gaps in the evidence base. Our review was narrative rather than systematic, aiming to draw out the main themes in the literature (including review papers and original empirical studies) to illustrate behavioural and psychological insights on low-carbon transport futures.

### *2.2 Elite interviews*

Potential interviewees were identified from the research team's network of academics and practitioners. Consequently, all were European (and most from the UK) but the questions posed did not restrict interviewees to only European evidence or experience. Potential interviewees were selected based on their track-records of expertise (i.e., research publications and employment experience) in mobility. Given that these individuals had influence and/or possessed particular expertise, they could be considered "elite" in their field and so an elite interview methodology was adopted (Burnham et al., 2004; Lilleker, 2003). Twenty-two European experts were contacted by email in late 2017 and 2018, of whom 11 participated (ten UK-based and one German-based). Interviewees represented different areas of expertise, including automotive industry, travel behaviour, transport futures, electric and autonomous vehicles, transport governance, and transport planning. This sample represents broader expertise than the modelling communities previously used to categorise academic schools of thought in relation to low-carbon transport futures (namely, into fuel composition, efficiency and infrastructural measures; Cruetzig, 2016). Nevertheless, while the interviewee sample is not large, it reflects a diversity of transport visions and policy solutions ranging from vehicle technologies to broader systemic approaches (Table 1). Furthermore, for qualitative research, depth of data is more important than numbers of respondents; and adequate sample size is determined based on when 'saturation' is reached (i.e., no unique themes emerge; Guest et al., 2006).

*Table 1. Interviewee details*

| | *Expertise* | *Sector* | *Gender* |
|---|---|---|---|
| Interviewee 1 | Automotive industry (business) | Academic | Male |
| Interviewee 2 | Future transportation | Industry | Male |
| Interviewee 3 | Autonomous vehicles (electronics) | Industry | Male |
| Interviewee 4 | Travel behaviour (psychology) | Academic | Male |

| | | | |
|---|---|---|---|
| Interviewee 5 | Transport engineering | Industry | Male |
| Interviewee 6 | Transport planning | Industry | Female |
| Interviewee 7 | Autonomous vehicles | Industry | Male |
| Interviewee 8 | Sustainable transport | Industry | Female |
| Interviewee 9 | Electric vehicles (psychology) | Academic | Male |
| Interviewee 10 | Transport governance and sustainable travel behaviour | Industry | Female |
| Interviewee 11 | Transport forecasting | Industry | Female |

The interviews took place in November 2017 and November-December 2018, lasted approximately 40 minutes and were conducted by telephone. A semi-structured method was used and questions were open-ended to maximise interviewees' expression of their opinions (Gall et al., 1996). The interviews were recorded and transcribed for analysis. Questions were developed to examine interviewees' views about citizens' transport decision-making now and in the future. The questions were: "What, in your experience, are the main influences on people's current decision-making about how they travel?"; "What are people's attitudes to different transport technologies and modes?"; "What would you say are the main drivers and/or barriers to transport users taking up new transport technologies and services?" and "What factors or trends might influence how people make decisions about how they travel over the coming years, up to 2040?" Interviews were analysed using template analysis (Brooks et al., 2015) with the narrative review informing the generation of initial template themes based on the niches of interest, namely EVs, CAVs, shared modes, and mobility substitution.

## 3 Results

In this section, findings from the interviews have been integrated with the findings of the narrative review. Interviewee (Int.) numbers are indicated in brackets after each quote. We structure the findings around the MLP categories of regime (Section 3.1) and niches: radical vehicle technologies (3.2), shared mobility (3.3), and mobility substitution (3.4).

### 3.1 Transport regime: ICEVs and personal mobility

The factors argued to be associated with personal ICEV dominance can be divided into structural and individual factors. For instance, there is an increasing necessity for citizens to have access to a car for travel for both work and leisure, at least partly due to car-dependency (Lucas, 2009). Private cars provide a particular combination of destination and route flexibility, immediacy of departure time, and a competitive door-to-door journey time with respect to other transport modes. Hence, locations for activities such as employment or shopping can be (and over recent history have been) selected with increasing distance from residences, with providers of goods and services often assuming that people can and will use their cars to cover the distance (Metz, 2008). The built environment has evolved to support the use of the private car, through increased road capacity (see Figure 1), prioritisation of cars within highway management policies (Banister, 2002), and the allocation of land and highway space for parking, often at below-market value (Shoup, 2005). Although car-oriented land use and transport planning has been halted or reversed in some places, critically, these structural factors may interact with transport users' perceptions of structural barriers. This means that an important element of whether people will switch to alternative modes of transport is their perceptions of the feasibility of using alternatives and their confidence in their ability to do so (Klöckner & Friedrichsmeier, 2011). These considerations, alongside others, are typically discussed in terms of an individual's perceived behavioural control (PBC) and are strongly associated with car use and using alternative travel options (Hoffman et al., 2017).

Such (perceived) infrastructural constraints are not the only reason that personal car use is often the preferred form of transport for individuals (Karlsson et al., 2016). Ownership of a standard road vehicle may also be preferred due to the accumulation of cultural and symbolic value of cars (Urry, 2004; Whitmarsh & Köhler, 2010; Kanger & Schott, 2016). For instance, owning a vehicle is often perceived as a symbol of status (Steg, 2005), whilst the vehicle itself may be perceived by an individual as representative of his or her self-identity (Barbarossa et al., 2015; Kressmann et al., 2006). This is consistent with evidence that mobility choices more generally can express aspects of social or self- identities (e.g., as 'global traveller', 'tech-savvy', 'green', 'responsible parent', 'successful'; Belk, 2007; Murtagh et al., 2012).

The perception that a car affords independence is often also reported to be an important motivation for car-use and ownership (Hagman, 2003). This perception captures the access, flexibility, reliability and convenience that a car is perceived to afford, as well as a more fundamental feeling of being in control compared to other forms of transport such as buses and trains (Gardner & Abraham, 2007; Mann & Abraham, 2006; Hiscock et al., 2002), even if cars can suffer breakdowns and journey-time unreliability due to congestion. Indeed, a car is often felt to be a symbol of freedom as well as independence (Jensen, 1999; Steg, 2005). However, this is not limited to car-users as users of different transport modes have been found to talk about the personal independence that their own travel modes afford them (Thomas et al., 2014; Hiscock et al., 2002). Therefore, whilst strongly associated with cars, the psychological benefits that a transport mode provides are likely to be very subjective to the traveller. Thus, as well as meeting personal mobility necessities, or providing the utility of travel, transport choices may be an important way in which the core psychological need for autonomy is fulfilled (Ryan & Deci, 2000). In this context, the reduction in interest with the personal car as being the primary tool of mobility may be linked to understandings of 'freedom' and 'independence' which emphasise not being tied to a specific mode, or an onerous hire purchase contract, or needing to take responsibility for servicing and licencing obligations. These motivations are considered further below in Section 3.2 in the context of factors encouraging membership of shared-ownership car clubs.

### 3.2 Radical vehicle technologies

Ceasing the use of fossil-fuels to power vehicles is widely considered critical for reducing the impacts of transport on climate change. EVs in particular, are argued to offer some pro-environmental advantages relative to ICEVs (Chapman, 2007). Consequently, EVs have been extensively researched regarding public perceptions and behaviour (Coffman et al., 2017). This literature highlights that 'early adopters' of EVs are more likely to be male, with higher income and education, and more motivated by environmental commitments than mainstream vehicle consumers (Graham-Rowe et al., 2012; Coffman et al., 2017). Amongst the mainstream, lack of acceptance of EVs stems from an unfavourable comparison to ICEVs on the instrumental factors of higher purchasing costs, actual and perceived limitations on maximum range (due to constrained battery capacities), charging times, and limited availability of public charging infrastructure (Carley et al., 2013; Graham-Rowe et al., 2012; Jensen et al., 2013). Whilst interviewees discussed the perception of EVs having limited range as being a barrier to people adopting EVs, it was also felt that the rate of charging, in particular, is problematic:

> *"I don't think range anxiety exists. I think it is charging time anxiety. If you could charge up your electric vehicle in the same time it takes to fill up a petrol car, for example, I don't think people would be too worried. It's the fact that it takes half an hour to get 80% of the charge back in, that's where the deterrent is, I think, rather than the range. Cars can have a limited range so long as they are quick to refuel." [Int.1]*

This view reflects the literature where the concerns relating to battery capacity, charge times and public charging infrastructure have been found to interact. For instance, concern for battery capacity (i.e., range anxiety) decreases if charge times are shorter and/or if more public charging infrastructure is available (Dimitropoulos et al., 2013; Coffman et al., 2017). The location of fast-charging stations is also important to users (Philipsen et al., 2016), although some willingness to detour for charging has been found (Sun et al., 2016).

Psychological factors associated with acceptance of EVs include an individual's identity and social influences (Sovacool, 2017). As noted, EVs have been promoted as more environmentally-friendly alternatives to traditional cars (Adwari et al., 2017). Accordingly, those who have a pro-environmental self-identity (i.e., see themselves as a 'green' person) are more likely to have positive perceptions of EVs (Schuitema et al., 2013). Similarly, being an early adopter of a 'green' technology is a source of positive identity for some EV users (Graham-Rowe et al., 2012). Furthermore, compared to the instrumental attributes of purchase cost, maintenance cost, fuel cost, charging convenience, and estimated EV range, belief that owning an EV will promote an image of being pro-environmental has a stronger, positive association with impressions of and willingness to buy EVs (White et al., 2017). In terms of social influence, interpersonal communication (i.e. the exchange of information between two or more people, including through social networks), neighbourhood effect (observing those in close proximity), and conformity with social norms (what people do and think they should do) have an effect on individuals' vehicle choices. Further, social influences have been found to compensate for some of the negative effect of higher costs or lower ranges of EV options (Pettifor et al., 2017). It is plausible that different social influences operate at different stages of EV adoption (as suggested in the reflexive layers framework; Axsen & Kurani, 2014): an actor might initially become *aware* of EVs through social networks; they then *assess* the EV's social and personal advantages as a product – is it both 'green' and useful; finally, the EV and its use become part of the actor's *self-concept*.

Whilst EVs deviate from the traditional ICEV in relatively limited ways (e.g., different charging practices; somewhat different driving and parking practices), AVs and CAVs are more radical in their potential to disrupt current driving choices and behaviour (Krueger et al., 2016; Shergold et al., 2016). It has been argued CAVs will offer environmental benefits through more efficient, coordinated driving (Howard & Dai, 2014), financial and time savings via the possibility to engage in work and leisure activities whilst being transported in a vehicle (Le Vine et al., 2015), greater mobility for those currently unable to drive (e.g., disabled, children; Fagnant & Kockelman, 2015, older adults who do not drive or have given up driving: Morgan et al., 2017), other user benefits (e.g., information and entertainment functions) due to increased connectivity (Voinescu et al., 2018), and greater safety through reduced crash risks (Bansal et al., 2016). These potential benefits are found to relate to positive perceptions of CAVs, particularly the belief that they will reduce the risk of road traffic incidents and collisions (Schoettle & Sivak, 2014; Bansal et al., 2016). However, some, including Merat et al., (2014) and Morgan, Alford and Parkhurst (2016), have warned of the possible dangers of AVs and CAVs that can drive autonomously without human intervention some of the time but may require handback (i.e., Level 3 – Conditional Automation; SAE, 2016) as the amount of time required to take back vehicle controls (steering wheel, pedals, etc.) and drive in a similar manner to normal (e.g., without sudden acceleration or braking and maintaining lane position) can be high: up to 20 seconds at 20mph according to Morgan et al. (2017). Interviewees also raised concerns that there is currently not enough evidence that CAVs will create the benefits that many argue they will:

> *"Around autonomous vehicles, I think there's a lot of assumptions. For example, autonomous vehicles will help improve congestion. And there's still not enough evidence behind that. So I think there's a role there for government to step up and potentially be commissioning pieces of work to really understand this." [Int.2]*

This view that more evidence is needed to support the CAV claims, which are key underpinnings of public perceptions, was in turn discussed as a general uncertainty about how individuals will use CAVs as part of their travel decision-making. For instance, the potential environmental benefits of CAV adoption by current drivers could be offset by adoption of CAVs by people who would have otherwise used more environmentally-efficient modes.

As with EVs, concern for the cost of CAVs, relative to conventional cars, has been found (Haboucha et al., 2017). Concerns that are more unique to CAVs are related to safety for both passengers and other road users (Schoettle & Sivak, 2014), fear of technical failure (Bansal et al., 2016), concerns about cybersecurity (Bansal et al. 2016; Schoettle & Sivak, 2014; Kyriakidis et al., 2015), willingness to share data (Anastasopoulou et al., 2018) and concerns relating to the adequacy of CAV laws and liability (Fraedrich & Lenz, 2014; Howard & Dai, 2014). Interviewees felt that, whilst cybersecurity may be an issue, it would be a low priority for the public compared to the safety of the CAV itself:

> *"It is perhaps the security of the vehicles that is the key issue there rather than the cyber security of the systems, the privacy aspect of it." [Int.3]*

In addition, unwillingness to relinquish control of the vehicle may negatively influence acceptance CAV adoption (Howard & Dai, 2014), particularly for individuals who experience pleasure from driving. Related to this, emotional responses to CAVs are important, with anticipated anxiety negatively influencing attitudes and anticipated pleasure positively influences attitudes, which may partly account for diversity of public responses to CAVs (Hohenberger et al., 2016).

Perceived trust is emerging as an important factor for CAV acceptance (e.g., Choi & Ji, 2015; Morgan et al., 2018). For example, in one AV simulator study (Korber et al., 2018), when participants were instructed to trust CAVs ("trust promoted" group), they engaged more with a non-driving related task and looked less at the dashboard instruments and road ahead compared to those who were instructed to mistrust CAVs ("trust lowered" group). Furthermore, those in the "trust promoted" group took longer to take over the controls following a handover request and were more likely to collide with an obstacle compared to those in the "trust lowered" group. Evidently, trust in existing technology (i.e. human-driven vehicles) is much higher than in new technology; one study found CAVs would need to be two orders of magnitude safer than human-driven vehicles before half of respondents would accept them (Liu et al., 2018). Similarly, interviewees recognised the importance of users having CAV experience for their acceptance:

> *"It's very important…giving people that taster, in an open environment where people can come in and test out services, just as you would with going to try a new vehicle anyway...the response we've had from the work we've been doing is very positive."* *[Int.2]*

This is in line with the finding that, although a statistically significant difference was not found in the sample as whole, amongst older participants (≥60-years) trust in AVs increased following their simulator experience (Gold et al., 2015). It is noteworthy that trust may generally be higher in CAV simulators compared to road-based CAVs and early evidence may not provide enough evidence to anticipate how driver behaviour and travel decision-making will change with CAVs (e.g., Morgan et al. 2018).

Related to experience being necessary for trust in CAVs, interviewees also felt experience was necessary to challenge expectations of who CAV users are. Interviewees felt that, amongst the public, there could be a misperception that CAVs are only for certain demographics or for those with an interest in technology as opposed to the mainstream:

> *"I think often the immediate perception amongst people is that generally younger more tech-savvy people are more open to this technology and perhaps older people less so. I think for many people that's an initial barrier…people not being open to change, but actually, once they've experienced that change they actually become more open to it".* *[Int. 2]*

While the importance of familiarity and different user profiles for technology adoption has been known for some time (Rogers, 1983), here the mediating factors of trust and identity appear to be key for CAVs, since they represent a fundamentally different mobility experience for most people.

### 3.3 Product-to-service shift (shared mobility)

At the intersection of ICT and shared transport modes, technological and business model innovation are encouraging and supporting a reduction in car ownership, by providing an access-based transport system as opposed to an ownership-based one (Jittrapirom et al., 2017; Kamargianni et al., 2016). For example, it is estimated that the average vehicle in the UK is parked at home for 80% of the time and parked somewhere else for 16% of the time (Bates & Leibling, 2012) and carries an average of 1.58 people (1.42 in Germany and 1.38 in the Netherlands; European Environment Agency, 2010), highlighting the potential for more shared forms of mobility, at least asynchronously. Indeed, models of shared transport can be divided into those which offer asynchronous 'one at a time' sharing of a vehicle (or bicycle) and those that offer the sharing of a journey (buses, trains, ride-sharing). Models of shared transport can then be further divided into business-to-consumer (free-floating or station-based) and peer-to-peer. Each model has its own barriers and facilitators to adoption and use, and consequently each attracts different user groups (Becker et al., 2017; Matyas & Kamargianni, 2018). For example, car-sharing clubs appeal to social and environmental activists and innovators as well as those more financially or pragmatically motivated, and is popular amongst women, students and bus users (Burkhardt & Millard-Ball, 2006; Zhou, 2012). Overall, packages of mobility services (MaaS) are likely to appeal most to infrequent car users and least to frequent car users; with free-floating services (including taxis) preferred to station-based or public transport (Ho et al., 2018; Matyas & Kamargianni, 2018).

While the consumer adoption/use literature for shared mobility is currently limited, initial, field trial evidence indicates participants' satisfaction being increased by the perceived attributes of simplicity, choice, accessibility, flexibility and economy, with the result being a reduction in personal car use in favour of shared transport and walking (Karlsson et al., 2016; Sochor et al., 2015, 2016). Modelling-based research similarly indicates the potential for car-sharing, bike-sharing and ride-sourcing services to reduce transport-related energy consumption by up to 25% (Becker et al., 2018). However, the broader literature on shared mobility suggests a more complex picture with, for example, ride-sourcing app-based services offered by 'transportation network companies' (TNCs e.g., Uber, Lyft) likely to replace not only taxi and personal car use trips but also public transport trips (Rayle et al., 2016). Specifically on the impact on transit services however, Hall et al. (2017) found considerable variability on the effect of Uber on transit services; with transit in smaller cities being potentially more affected, but overall a complementary effect. The implications for overall vehicle travel (and associated environmental and health impacts) therefore remain unclear (Smith et al., 2018).

From a socio-psychological perspective, the *shared* nature of the new models of mobility compared to conventional vehicle ownership models raises important issues pertinent to this paper. As use of personal cars is the prevalent transport choice, it is perhaps understandable that many studies compare the use of other forms of mobility, such as shared or active, with the personal car (Hoffman et al. 2017). In such studies, personal cars are frequently found to be evaluated more positively on determining instrumental and affective factors compared to shared options (Clauss & Döppe, 2016). However, interviewees felt that there is a rising trend (in the UK and beyond) in shared transport use, albeit one that is not evident at the moment:

> *"Shared ownership models; that's a growing trend. We're seeing this shared access versus private ownership. I don't think there's enough hard evidence behind it yet…it does seem that there is a growing shift towards shared ownership, particularly among*

*certain demographic groups. For example, I don't own a car. That's not because I can't; it's a choice because I can go and hire a car very easily and it's more affordable that way." [Int. 2]*

Important aspects of accessing shared transport are highlighted in the above quote: the demographic of the current users, the choice to use it, and affordability. A number of interviewees felt that it is predominantly younger adults who live in urban centres who are utilising shared transport, which some literature on car sharing supports (Becker et al. 2017; Green et al. 2017; Schmöller et al., 2015; Le Vine & Polak, 2017). One proposed reason for this is a change in the association between car ownership and status noted above; interviewees believed it to be weakened, specifically amongst children and young adults:

*"Are people happy not having their own [car]? Again, I think it's a status thing, I think, which again, is changing because there is a change in what is a status symbol. It used to be you've not made it if you're still taking the bus...but I think generations coming through don't see that, so I think attitudes are changing." [Int. 6]*

In contrast to Interviewee 2, who felt he could afford to own a car but choose not to, Interviewee 4 felt that there will be those who use shared transport due to circumstance, but would choose a personal car if they could:

*"Young people not owning cars is an interesting one…The evidence I have seen, which isn't much, is that they are on the bus because they can't afford a car and, in most cases would be in a car if that option was open to them." [Int. 4)]*

As such, an important factor in decision-making related to public transport (as well as shared transport more broadly) is affordability and aspirations. For instance, it may be important to distinguish between public transport users who are "reluctant riders" (involuntary users of public transport who use it due to health or financial reasons, but aspire to owning a car) and those who are “car-less crusaders” (do not aspire to own a car for environmental or autonomy reasons and have positive perceptions towards alternative modes; Anable, 2005).

Affordability and choice, as well as the instrumental quality of the public transport experience, are likely to further interact with the individual’s current life-stage and circumstance, which may change and result in different transport choices:

> *“And then they reckon that once people start having families, they move out to the suburbs, have a bit more room and can afford to buy their own car.” [Int. 1]*

Therefore, an important aspect for maintaining the use of shared transport as opposed to adopting personal mobility and car ownership is to understand whether it is a choice predominantly motivated by values (e.g., environmental concern) or (perceived) necessity (e.g., affordability, life-stage). Indeed, perceiving use of a shared-ownership car to be reliable and compatible with one’s lifestyle has been found to be an important factor in continued use of shared-ownership vehicles: whilst cost savings increased users’ satisfaction with car sharing, it had no significant effect on the likelihood of the user choosing a sharing option again (Kim et al., 2017). However, greater belief in the utility of car sharing (that car sharing fulfils the same needs as owning a car) was associated with a greater likelihood of choosing a car share again (Kim et al., 2017).

Individual perceptual factors also play an important role in individuals’ use of shared transport. For instance, whilst ownership has benefits (including control and accessibility; Moeller & Wittkowski, 2010), there are also drawbacks to ownership, which may reduce individuals’ desire to own products. These drawbacks have been discussed in terms of burdens of ownership, which include both risks (obsolescence, incorrect product selection, depreciation of value) and responsibilities (maintenance, repair, the full cost) associated with owning an item (Belk, 2007). In a US study of car share users, perceived financial risk (‘uncertainty regarding the potential financial loss that a purchase decision may result in’ p.571), performance risk ('uncertainty about whether a product will perform as expected' p.573) and social risk ('the extent to which purchase decisions are believed to be judged by others and may influence one's social standing' p.573) of owning a car were all positively associated with greater usage of car sharing services (measured in total minutes used). In turn, greater car share usage was positively associated with car ownership reduction (i.e. selling their car; Schaefers, et al., 2016).

Functional (complexity and reliability) and psychological (contamination and responsibility) barriers to shared vehicle use have also been identified. For instance, perceiving the sharing service as difficult to access or use and feeling dependent on the reliability of other people using the service properly (e.g. returning the vehicle on time) act as barriers to using a shared service. Here, there may be significant spatial variations in perceived and actual barriers to shared mobility, though rural populations may nevertheless be open to using them (Wappelhorst et al., 2014). Furthermore, a perceived risk of being 'contaminated' by previous users and a concern for being responsible for looking after something that one does not own also act as barriers to using shared services (Hazée et al., 2017). Amongst users of shared cars, these barriers are attenuated by changing travel habits (e.g., shifting to less popular travel times), postponing needs (e.g., waiting until a vehicle is available) or seeking alternative solutions (e.g., public transport). Indeed, while there is clearly a role for suppliers to ensure optimal vehicle availability and usability, there is also an 'active, central role of customers in the barrier-attenuating process' (Hazée et al., 2017, p.452,) as the user must choose to engage in these cognitive processes to overcome a perceived barrier to shared vehicle use. Identifying the psychological traits of those who are willing, or not, to overcome the barriers will be important for future car sharing success (Hazée et al., 2017), although perhaps implicit in this approach is the expectation that sharing will be a market niche, albeit a substantial one, rather than the near-universal norm.

Finally, a significant barrier to changing travel choices – including shifting from personal motorised modes to ones that are shared, public, or active – is habit (Verplanken et al., 1997). This could at least partly explain why consumers prefer to continue using their current modes (e.g., public transport, taxis) than switch to new modes (e.g., bike-sharing, car-sharing; Matyas & Kamargianni, 2018). This is related to, though not the same as, consumers' preference for familiar modes and technologies and the importance of prior experience in technology/service acceptance noted earlier (e.g., Rogers, 1983). Habits – being efficient but less conscious responses – attenuate attention to new information, so serving to lessen the efficacy of behaviour change interventions that rely upon attention being given to new information (Verplanken & Wood, 2006). Habits are automatic behavioural responses to contextual cues (e.g., having to go to work), and because they are learnt from repeated successful actions taken in stable contexts, they are disrupted when contexts change – for example, when a highway or train line is closed (Fujii et al., 2001) or one moves house (Verplanken & Roy, 2016) or office (Walker et al., 2015).

### 3.4 Mobility substitution

As noted in Whitmarsh (2012; cf. Urry, 2011), most socio-technical transitions studies 'involved a transition to different, but also *more*, consumption of technical innovations and of resources [whereas] a sustainability transition – within transport or any other domain – is likely to be a transition to *less* consumption' (p.486). This may highlight a limitation of the MLP, but equally reflects a policy preference for technological solutions to environmental problems (Hajer, 1999). Yet – as noted by interviewees – neither EVs nor CAVs are currently able to tackle all the challenges associated with the current transport regime:

> *"[EVs and CAVs] still carry around four empty seats most of the time, that still requires no physical activity from the driver, that still dominates the urban space. It is business as usual really". [Int. 4]*

Understanding how different social practices might substitute for others in a socio-technical transition (e.g., cycling cultures replacing car cultures; Aldred & Jungnickel, 2014) is one example of how the MLP might be extended to apply to mobility substitution. On the other hand, one strength of the MLP (and broader transitions literature) has been to explore system-wide change and include diverse and minority perspectives which might otherwise not be considered in policy or innovation debates. Groups that are not served well or are excluded by the current ICEV-dominated regime (e.g., disabled, low income) may be served better by more 'radical' alternatives that are not merely 'technofixes' (albeit, they may include some technological innovation). Reducing the need to travel, for example, is likely to benefit such groups, as well as affording a range of benefits to all users (e.g., improved air quality, lower emissions, fewer collisions). Two approaches for reducing overall demand for motorised transport are reviewed here.

A critical factor in deciding whether to engage in an active form of transport, i.e. walking or cycling, is the characteristics of the built environment, including interconnection or streets and accessibility, such as proximity to work and shops, and provision of parks and green spaces (Ewing & Cervero, 2010; Smith et al., 2017). However, how the built environment is viewed is also important, with perceived presence of local amenities and perceived supportive infrastructure (including convenient, pleasant walking routes) positively relating to increased walking, including within urban city-centre environments (Bornioli et al., 2018), and greater street connectivity positively relating to cycling (Adams et al., 2013). Perceptions of risk are negatively associated with cycling, with the availability of segregated cycle paths moderating the association (Wardman et al., 2007). Indeed, interviewees felt that it is not primarily a change in an individual's attitudes that motivates an uptake of active transport, but rather their social and physical context:

*"To give a clear, but anecdotal example; everyone who moves to Cambridge starts cycling – it's not as if they undergo an attitudinal shift or a value shift. Some of these models would suggest they have to, but it's just that's what the social and physical environment facilitates, so therefore, people start doing it." [Int. 4]*

The literature provides a more nuanced picture of *interacting* psychological and contextual factors. For example, Chatterjee, Sherwin and Jain (2013) proposed that a change in contextual factors, such as a life event (e.g., moving home) is important for prompting a deliberation of starting to cycle, with facilitating conditions (e.g., presence of off-road cycle routes), intrinsic motivations (e.g., to be healthier), and previous cycling behaviour acting as mediators.

As with public transport, it is important to note the distinction between those who walk out of preference and those who walk because other forms of transport are not available to them. This is perhaps highlighted by perceived 'pleasantness of the route' being positively related to the decision to walk in a more affluent sample, but not in a less affluent one (Ogilvie et al., 2008; Panter et al., 2011; a finding echoed in several studies – see Smith et al., 2017). In both samples, however, the importance of accessibility (as proximity) in decisions to walk or cycle was found, with Panter et al. (2011) finding this to be more important than psychological factors (attitudes, perceived behavioural control over fitness, social norms and habits).

How digital technologies are influencing people's awareness of the amount of physical activity they undertake was raised by an interviewee, who pointed to the use of wearable activity trackers:

*"People being more aware of how much activity they are doing and getting more information about that…my guess is that is only going to get more sophisticated over time" [Int. 9]*

The greater information provided to the user may enable them to factor in their previous, current and desired activity rates when making their transport decisions. Indeed, there is evidence for some forms of wearable activity trackers increasing the physical activity of users

(Cooper et al., 2018), although a decrease in use over time may reduce effects (Simons et al., 2018). More generally, positive emotional responses to active travel may also be important. For instance, walking and cycling are more associated with relaxing, interesting, pleasant and exciting responses, whilst public transport and car use are more associated with boredom, stress and unhappiness (Chng et al., 2017; Gatersleben & Uzzell, 2007).

Telecommuting (or working from home) represents a significant opportunity to reduce transport demand related to commuting (Capstick et al., 2015) and associated emissions (Fu et al., 2012), albeit potentially also reducing human and social capital due to lower employee motivation and interaction (Kalinowska-Sufinowicz, 2015). While telecommuting is not an option for all types of work, interviewees noted that it may increase in the future as ICT advances and employment opportunities change:

> *"Areas of economic activity might be less concentrated and more dispersed. We already see in some jobs more and more people working at home so conventional commuting might become less and less." [Int. 1]*

It is important to distinguish between the specific effects of teleworking and the larger effects of ICT in general: there is a persuasive argument that ICT in general tends to *increase* motorised travel (Mokhtarian, 2002; 2009), particularly in the light of a perceived historical correlation between volume of communications and volume of travel over the long run (Höjer & Mattsson, 2000). The *specific* effects of teleworking *in vivo* are a separate question, however, and these effects are mixed and prone to 'backfire'. One form of backfire is the current use by long-distance workers to reduce the overall amount of time they spend travelling, rather than achieving this outcome by reducing travel distances and without resort to remote working. As one interviewee questioned:

> *"If employment isn't a main reason for travel, in the future, what will people do? Because travel time budgets have been fairly static for quite a long time" [Int. 10]*

For instance, it has been shown that telecommuting in the US is associated with an overall switch from motorised transport to physically active transport *on the days when workers telecommute*, but that their overall annual driving *is greater* on average - the *frequency* of teleworking days did not seem to offset the longer *commute-distances* of teleworkers (Chakrabarti, 2018; see also e Silva & Melo, 2018). Another form of backfire can occur at the household level, where a telecommuting 'head of the household' permits others in the household use of the car, actually increasing overall driven distance at the household level (Kim, Choo & Mokhtarian, 2015) – but there is not always evidence for this, (Melo & e Silva, 2017).

It is important to remember, however, that findings such as these reflect the mixed effects of telecommuting as it occurs now, *within* the current socio-technical regime of car-based mobility. Studies that consider the effects upon mobility substitution of atypically *high levels* of telecommuting (three or four days each week, rather than one day a week or less) find evidence that motorised travel is *reduced* at these levels (e Silva & Melo, 2018). So, given the other benefits in work and home life, as well as to businesses, that can accrue from teleworking (Gajendran & Harrison, 2007), a transition to *frequent* teleworking may be both desirable and lead to mobility substitution – exclusive teleworking may be being adopted gradually, or have yet to reach a tipping-point (Felstead, 2012; Vilhelmson & Thulin, 2016). Indeed, positive results have been shown in notable case studies (e.g., Government of State of California: Koenig, Henderson & Mokhtarian, 1996; British Telecom: Anable et al., 2004) and a review of 35 studies of telecommuting found that the majority of these studies (around 30) reported travel substitution effects, rather than increases, though the authors were critical of past research methodology (Andreev, Salomon & Pliskin, 2010). It may be, then, that widespread diffusion is hindered by occupational barriers, rather than anything related to travel (Mokhtarian & Salomon, 1997; Bailey & Kurland, 2002; Felstead, 2012).

The overall benefits of e-shopping for reducing personal transport use are similarly complex to determine (Andreev, Salomon & Pliskin, 2010; Suel & Polak, 2018), with imperfect review evidence for only marginal reductions in personal travel (Rotem-Mindali & Weltevreden, 2013; Weltevreden & Rotem-Mindali, 2009; Cairns, 2005) and relatively little insight on psychological factors involved (Jayawardhena, 2004). There is some evidence for the importance of individual differences in the decision to shop out-of-town, locally or online: a Californian study found that those who enjoy the shopping experience prefer to go out shopping (rather than buy online), those who are concerned about the local economy or the environment prefer to shop locally (rather than out-of-town) and those who like technology prefer to stay home and shop online (Lee, Ipek, Sener, Mokhtarian & Handy, 2017). Likewise, Zhai, Cao, Mokhtarian and Zhen (2017) studied the use of shops and the internet at different stages of product-buying (researching, trying and buying products) and found that goods where first-hand experience was important in buying decisions (like clothes) tended to be more often bought in a shop compared to other goods (although all the while retailers offer free returns for unwanted internet purchases, there will be an incentive for the home to replace the in-store fitting room; De Leeuw et al., 2016). This caution about the limits to e-commerce is also reflected in research showing that the perceived level of risk of shopping online (i.e., cybersecurity) and online retailer reputations are also influential in decisions to shop online (Kim & Choi, 2012; Bianchi & Andrews, 2012). For grocery shopping, Suel and Polak (2017) found that those who bought groceries online tended to be relatively wealthy, early adopters who used the technology as a substitute for ‘large-basket’ shopping trips, indicative of future reductions in out-of-town retail trips for grocery shopping assuming this technology continues to diffuse.

However, it is worth emphasising that much of the transport research in this area is relatively recent and limited with respect to psychological elements, being focused primarily on how to model behaviour more completely and accurately. By contrast, Elms, Kervenoael and Hallsworth (2016) approached this question qualitatively, using an 18-month in-depth ethnographic study of a small group of atypical online grocery buyers in the UK. They found ideographic motives for disliking shopping-trips but indicate that 'click and collect' services can address some of these. The implication for travel, however, is that each 'click and collect' is one more personal car-journey that might otherwise be saved. In short, while the overall effect of e-shopping on personal travel is unclear, there are indications that the benefits of e-shopping may be limited both by social and pragmatic affordances of in-store experiences and through services that provide the convenience of internet shopping without reducing personal travel.

## 4 Discussion

The current review has brought together the macro-level view of transitions represented by the MLP and many socio-technical transitions studies on the one hand, with, on the other, micro-level insights from psychology and allied disciplines. This synthesis has been applied to examine how the transport regime impedes innovation and how mobility niches might break through to challenge the regime. As such, we have begun addressing the under-theorisation of users and their behaviours in understanding low-carbon mobility transitions. Here, we bring together the findings from our literature review and interviews to address the research questions we posed at the outset and draw out implications for policy:

*How do socio-psychological aspects of the transport regime serve to impede transition to a low-carbon mobility system?* The ICEV ownership and personal mobility-dominated transport regime lock-in and constrain users' options in both physical and cultural terms, with hard infrastructure and identity associations tending to favour car-based personal mobility over alternatives (Urry, 2011). However, while this has been evident from previous mobility transitions studies (e.g., Nykvist & Whitmarsh, 2009), the current paper highlights important additional insights afforded by a socio-psychological perspective on mobility transitions. In particular, it is clear that emotional, experiential (i.e., experience-based) and social factors, as well as practical and financial aspects, shape transport choices; and that familiarity with transport technologies and modes combined with ingrained habits, are likely to act to lock-in behaviours at a psychological level, alongside physical and cultural factors that lock-in choices. On the other hand, our analysis highlights that lock-in is not uniformly or objectively experienced; rather, there is an interaction between individual (subjective) preferences and values on the one hand, and their (objective) socio-economic, transport and built environment context on the other, that together determine their perceived mobility necessities and their mobility choices. Consequently, it is critical not to over-state the influence of either structural factors or of attitudinal factors in influencing the potential for individuals to change their behaviour and potentially adopt lower-carbon mobility choices.

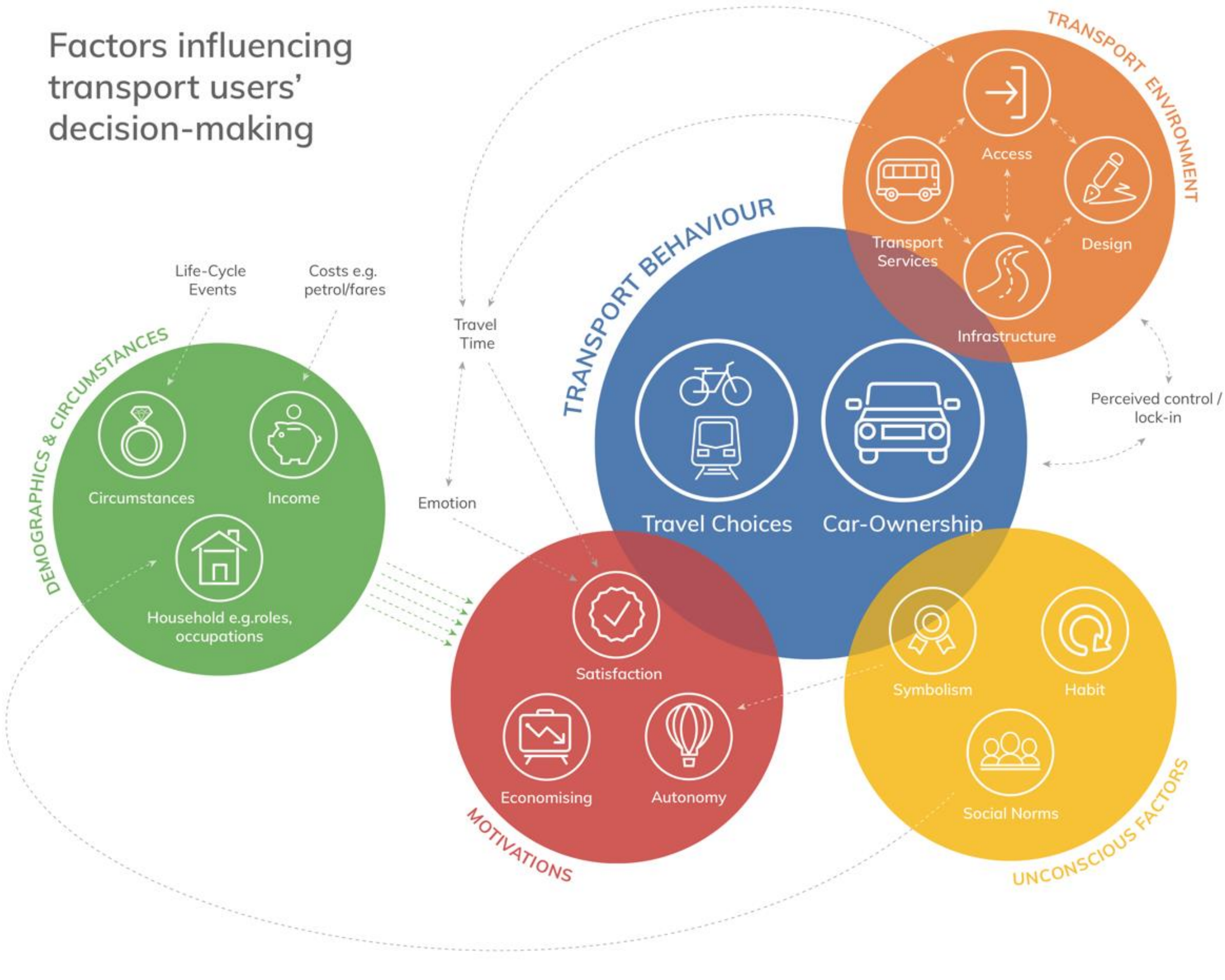
*How do (or might) users act as facilitators of, and barriers to, radical innovation in mobility systems?* Understanding psychological and social processes that inhibit behavioural change can shed light on how and why mobility innovations may (or may not) succeed. Assuming current trends of EV development and policy support, the costs, range and supporting infrastructure of EVs are likely to become more competitive with ICEVs (Wu et al., 2015). As such, cost and functional barriers to EVs adoption by mainstream consumers will be reduced (Coffman, 2017). At the same time, the lower running and maintenance costs (Hardman et al., 2016) and the perceived environmental benefits (Degirmenci & Breitner, 2017) are aspects of EVs which are compared favourably to ICEVs. Since EVs – as well as certain shared modes (e.g., ride-sourcing services) – are becoming more commonplace, familiarity and trust will increase and social norms will evolve, facilitating their adoption. Users' roles in innovation processes are therefore to act not only as 'economic actors' to drive up demand and bring down costs, but also as 'social actors' to embody and augment social norms around adoption and 'domestication' of new vehicle technologies and modes (cf. Lie & Sørensen, 1996).

On the other hand, CAVs represent a more radical and less familiar prospect for most people; and so trust may be harder to establish, as is often the case with many forms of technology automation (e.g., Lee & See, 2004), and maintain once achieved (e.g., Choi & Ji, 2015; Parasuraman & Riley, 1997). Here, though, we know from innovation and transition studies that users can adopt pro-active roles in successful innovation diffusion, exposing new functionalities (e.g., using CAVs as semi-public places for social or leisure pursuits) that in turn create new market opportunities and radically reconfigure socio-technical systems (Geels, 2005). Understanding the multiple identities that individuals have (e.g., as a 'parent', 'worker', 'cyclist'; Murtagh et al., 2012) and their affective experiences when travelling may provide additional insights into how radical technological innovation may help fulfil individuals' social and psychological roles and needs.

Equally, understanding these roles and needs, along with citizens' relationships with institutions (e.g., trust in government or other people), can elucidate why individuals might oppose policies to discourage or restrict certain mobility options; for example, fuel taxes or congestion charges may be seen to constrain individuals' abilities to travel for work or family reasons, if alternatives are not perceived as viable (Xenias & Whitmarsh, 2013; Schuitema et al., 2010). Other work shows that people tend to exaggerate the positive aspects of their current travel mode relative to alternatives in order to justify their choice to themselves and others (i.e., motivated reasoning) acting as a further psychological barrier to change (Kunda, 1990).

*What opportunities exist, or could emerge, to align policy delivery with users' preferences and behaviours in order to promote low-carbon mobility options?* The literature highlights that individuals have various motivations for travel choices, and that these include autonomy, economy (financial and time), hedonic, health, social and environmental (Whitmarsh, 2009; see Figure 1). While some individuals may be motivated to adopt low-carbon mobility choices for environmental reasons (e.g., ‘car-less crusaders’; Anable, 2005) most will do so because they represent more convenient, cheaper or healthier options (Barr, 2018). As discussed, social norms and identities will also shape mobility decisions.

*Figure 1. Factors influencing transport users’ decision-making*




Implications for interventions to foster low-carbon mobility choices therefore include both ‘hard’ and ‘soft’ measures. Infrastructures need to be reconfigured to reduce actual and perceived barriers to behaviour change; while informational and social interventions are required to ensure individuals try to become familiar with these new technologies and modes. Offering free trials of CAVs or new forms of shared mobility, particularly at times when habits are disrupted (Verplanken & Roy, 2016; Bamberg, 2006), may increase familiarity and help address misperceptions about the viability or quality of alternatives compared to current choices. Segmenting users may help ensure that messages are targeted to the different motivations and needs of different groups; for example, promoting the health benefits of active travel or the cost savings from car sharing (Barr, 2018). Intervening to make regime mobility choices less attractive and viable (e.g., road user charging) in tandem with making niche options more attractive and viable (e.g., subsidising shared modes; providing kerb-separated cycle lanes) could both avoid public backlash and create sustainable low-carbon habits (Anable et al., 2004). Consistent with this, it is also important to distinguish between those who are in a financial position to make choices and those who are limited in their choices (i.e. ideally people will use low-carbon options out of choice rather than financial necessity). For some groups, sharing ownership, or not owning at all, may already be acceptable and preferable. For these, it is important to understand how this preference can be maintained across their moments of change (e.g., starting a family).

Our review was not systematic, but rather aimed to draw out the main themes in the literature to illustrate insights on low-carbon transport futures from bringing together previously disparate literatures. In particular, our review focussed on land-based personal travel, which is critical for a low-carbon mobility transition; but other transport areas such as freight and aviation are also important. Indeed, the rapid rise of e-commerce and both leisure and professional air travel have important socio-psychological dimensions which we have only briefly addressed here. Future work should extend the current approach of integrating transitions and behavioural and psychological literatures to examine innovations in these areas. Our review did not explicitly rate the quality of the evidence base, but we have noted where gaps and weaknesses exist; in particular, the socio-psychological aspects of autonomous and shared mobility remain relatively under-researched compared to electric mobility. In addition, our expert interview sample was relatively small (albeit reflecting diverse areas of expertise) and largely confined to the UK; but ideally a more comprehensive and culturally diverse review would have recruited experts from other (including developing) countries. Furthermore, we did not interview non-expert groups, although we incorporate studies in our literature review which have done so (e.g., Xenias & Whitmarsh, 2013).

## 5 Conclusion

Operating within the MLP framework, the exploration of users' perspective on the socio-technical transition to low-carbon transport has shed light on the ways in which psychological and social factors can impede or facilitate a low-carbon mobility transition. Of the three niche categories we explored here, technological change may be most compatible with the regime but potentially affords a narrow range of sustainability benefits, while mobility substitution may be most challenging for both policy-makers and publics while potentially addressing a wider range of sustainability problems associated with the transport regime. This extends Sovacool's (2017) work on 'socio-material commensurability', namely compatibility of innovations with existing material infrastructure and lifestyles. EVs and CAVs may be materially incommensurate with the regime in certain ways (i.e., requiring new charging infrastructure, smart highways, etc.), but neither fundamentally challenge values or norms associated with 'automobility' or with a more general policy preference for technocentrist approaches to addressing sustainability (O'Riordan, 1981). Owning a car (EV, CAV, or ICEV) still meets users' motives for autonomy and identity expression; and vehicle adoption (whether privately owned or shared) promotes technological innovation and economic opportunities.

Mobility substitution may meet different user needs, such as economising (money and time) or health, and in turn reduce air quality and address inequality and inaccessibility. Economic and technological opportunities to promote mobility management also exist, though involve actors outside the transport regime (e.g., ICT firms) and challenge entrenched policy assumptions that road building is required for economic growth (Sanchis-Guarner, 2012). Shared mobility options sit somewhere in between and challenge certain aspects of the regime (e.g., status associated with car ownership) while offering certain environmental, social and economic benefits and potential for technological (ICT) innovation. Of course, affording a range of sustainability benefits does not necessarily indicate the degree to which these benefits might be achieved or how trade-offs between sustainability criteria might be managed (e.g., reduction in air pollution versus reduction in obesity).

For all three areas of innovation, policy interventions need to address the needs, preferences, experiences and identities of users if they are to be effective and sustainable. At the level of technological innovation (e.g., for CAVs), considering user perspectives means attending to factors such as accessibility, usability, functionality, and adaptability, otherwise there is a risk that a suboptimal 'design-for-all' approach will be taken (Morgan et al., 2017, 2018). At the broader governance level, this implies more deliberative and participatory models of policy-making that incorporate users' and other stakeholders' perspectives (Whitmarsh et al., 2009), such as socio-technical transition management (Loorbach, 2007). So far this approach has been applied more to energy policy (e.g., in the Netherlands) than to transport, but its methodology for bringing together diverse expertise and values and moving beyond incremental change may offer a way of 'steering' a sustainable mobility transition that includes user perspectives (Kemp et al., 2007).

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