

The mobility of older people, and the future role of Connected Autonomous Vehicles

A Literature Review. Sept 2016

This document

This report was produced in the 'Flourish' Project, a successful participant in Innovate UK's *Connected and Autonomous Vehicles Collaboration Research & Development* competition. Flourish set out to identify innovative solutions that address two distinct but related topics within the connected and autonomous vehicle (CAV) market which are seen to help realise market readiness of CAVs in the UK:

- Customer Interaction focusing on the customers' needs and experience when using the technology; and
- Connectivity focusing on effective data analytics and ensuring that the cyber security and wireless connectivity elements of CAVs are safe by design.

Older adults with ageing-related impairments were seen to be particular beneficiaries of CAV technology, allowing them to continue to be active contributors to the economy and society. As a result the project has focussed on the needs of this group, hopefully accelerating their ability to become early adopters of CAVs. It is expected that by addressing the needs of older people that the knowledge, services and capabilities that will be developed will also be exploitable by other age groups. Consequently, the key objective for this review was to develop an understanding and articulation of current mobility needs, any existing experience of CAV (or components of it) and older people's future expectations of CAVs in respect of their mobility.



Document authors

Ian Shergold (UWE), Myles Wilson (OPM Group), Prof Graham Parkhurst (UWE)

With contributions from: Helen Ashley (Dialogue by Design), Matthew Cockburn (Bristol City Council)

Published: September 2016

Please address any queries or comments in relation to this document to:

Ian Shergold. Research Fellow
Centre for Transport & society
Department of Geography and Environmental Management
Faculty of Environment & Technology
University of the West of England,
Frenchay Campus
Coldharbour Lane
Bristol BS16 1QY
Tel: 0117 3281178
Email: ian2.shergold@uwe.ac.uk

Table of Contents

This document	ii
Context.....	v
Levels of autonomy	v
Categorising ‘Older People’	vi
Executive Summary.....	vii
1 Introduction to the review	1
1.1 Older people and out-of-home mobility.....	1
1.2 Review topics	1
1.2.1 Categorisation of older people	2
1.2.2 Flourish research participants.....	3
1.3 Snapshot: Older people in the UK.....	4
1.3.1 Current travel behaviour of older people in the UK	5
1.3.2 Trends in behaviour related to travel and transport	7
1.3.3 Mobility constraints	8
2 Literature review: User needs and experience	10
2.1 The role of out-of-home mobility, and specifically the use of motorised vehicles such as the private car or public transport, for older people.....	10
2.1.1 Benefits of out-of-home mobility	10
2.1.2 The impacts of reduced mobility	11
2.1.3 Conclusions	12
2.2 Variation in mobility needs across different groups of older people	14
2.2.1 Age	14
2.2.2 Gender	15
2.2.3 Location.....	16
2.2.4 Access to a car.....	17
2.2.5 Conclusions	17
2.3 Expectations of older people in respect of new technologies that will automate and connect vehicles	19
2.3.1 General opinions and willingness to use CAV	19
2.3.2 Comfort with levels of vehicle automation.....	21
2.3.3 Attitudes and preferences towards in-vehicle technologies	23
2.3.4 Conclusions	24
2.4 Experience of older people making use of existing in vehicle technologies and technologies that provide motorised mobility	25
2.4.1 Use and benefits of in-vehicle technologies	25
2.4.2 Learning how to use technologies	27
2.4.3 Mobility scooters	27

The mobility of older people, and the future role of Connected Autonomous Vehicles

2.4.4	Electric bicycles	28
2.4.5	Conclusions	28
2.5	Experience of older people being exposed to, or trialling connected and/or autonomous vehicles	30
2.5.1	Vehicle technology trials / studies involving older people	30
2.5.2	Other research activity in relation to older people and CAV	32
2.5.3	Conclusions	33
2.6	The user needs and expectations of those with some form of physical or cognitive impairment	34
2.6.1	Mild Cognitive Impairment (MCI)	34
2.6.2	Physical impairment.....	37
2.6.3	How might the deployment of CAV impact on these issues?	38
2.6.4	Conclusions	39
2.7	Opinions about future mobility for those approaching older age	40
2.7.1	'Baby boomers' and mobility in later life.....	40
2.7.2	Consideration of relevant policy perspectives.....	42
2.7.3	Conclusions	42
3	Conclusions	45
4	References.....	47

Context

Levels of autonomy

It is helpful in discussions around autonomous vehicles to have a clear understanding of what the term might mean. For example, there is a significant difference between technologies that already offer some element of autonomy, and where emerging technology could take vehicles in the relatively near future. SAE International¹ has looked to address the terminology issue through its recently issued: “*Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems*” summarised in Figure 1 below.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment						
0	No Automation	the full-time performance by the <i>human driver</i> of all aspects of the <i>dynamic driving task</i> , even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the <i>driving mode</i> -specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the <i>driving mode</i> -specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	System	Human driver	Human driver	Some driving modes
Automated driving system (“system”) monitors the driving environment						
3	Conditional Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> with the expectation that the <i>human driver</i> will respond appropriately to a <i>request to intervene</i>	System	System	Human driver	Some driving modes
4	High Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> , even if a <i>human driver</i> does not respond appropriately to a <i>request to intervene</i>	System	System	System	Some driving modes
5	Full Automation	the full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i>	System	System	System	All driving modes

Figure 1: SAE International standard J3016:Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems. (Copyright © 2014 SAE International).

This review has looked for source material that might relate to Level 4 and 5 as described above, but because to date such vehicles are relatively scarce, relevant material addressing some of the lower levels of automation has also been included.

¹ SAE International is a global association of engineers and technical experts in the aerospace, automotive and commercial-vehicle industries. The organisation has as a key function the development of ‘voluntary consensus’ standards in its fields of interest.

Categorising 'Older People'

Defining a boundary for older age is not straightforward. Pensionable age used to be a key marker, but the process of 'retirement' has become more flexible and transitional. Social expectations about lifestyles beyond the core years of employment have changed. For the purposes of this review, the term older people is taken to mean those aged 60 and above. This is not a hard and fast boundary, but might typically reflect the start of a decade when people might be thinking about retiring from regular work, be noticing the physiological effects of ageing on their physical and mental health, and making location decisions based on coming life changes (such as retirement for example). For some this happens earlier, and others later, but this is most likely to be the start of a period in people's lives where their out-of-home mobility begins to decline from the peak in their 40s and 50s (DfT, 2015). The review will also consider subgroups within this broad age category, for example specific age groups will be identified where research studies have reflected on them.

Executive Summary

Notwithstanding new technologies, and changing patterns of activity, mobility is still a fundamental requirement for inclusion in economic and social activity, including for older people. This latter group are though different to others in society, in that they are more likely to be experiencing constraints on their ability to be (independently) mobile as a result of age-related physiological or cognitive decline. CAV technologies arguably have a role to play in enabling older citizens to retain their mobility despite such changes.

This review focussed on seven questions examining the potential future role of connected autonomous vehicles for older people:

1. What role does mobility, and specifically the use of motorised vehicles such as the private car or public transport have for older people currently?
2. Do the 'needs' for mobility differ across the different groups of older people (younger old, older old, non-drivers).
3. What expectations do older people have in respect of new technologies that will automate and connect vehicles?
4. What experience is there of older people making use of existing technologies to provide motorised mobility?
5. What experience is there of older people being exposed to, or trialling connected and/or autonomous vehicles?
6. Are the needs and expectations of others with some form of physical or cognitive impairment similar or different?
7. Have people who are approaching older age expressed opinions about the sort of mobility they would like when they are older?

The review, also drew on a health and age-related categorisation in accordance with the groups that the Flourish project is concerned with addressing:

- People who are 70 and above now, expected to include people with minor cognitive impairments, but excluding those experiencing illnesses such as dementia and Alzheimer's disease.
- People of any age (over 18), who have physical and/or cognitive impairments that may preclude or inhibit / prevent driving or other forms of mobility / transport.

A contextual review of older people's mobility behaviour identified that cars continue to become more important for older people's travel, although with other modes of travel important for particular sub-groups and of greater importance for the older old. As might be expected, physical mobility shows a decline with age, but activity levels are more likely to be supported where individuals have a range of options. CAVs might assist in expanding this choice-set.

Whilst it can be argued that mobility is important at all ages, it is increasingly seen as a key factor in facilitating the 'quality of life' experienced by the growing older population (Parkhurst et al., 2014). In particular, the private car, the primary mode of transport for most people in developed countries such as the UK, is critically important (Shergold, Parkhurst & Musselwhite, 2012). The role of mobility for older people, and of the car is explored widely, both in the academic and policy-related literature, in national and international studies, and in the wider work of older people's advocacy groups. Important issues emerging from this literature concern older people's quality of life, their 'wellbeing' (Nordbakke & Schwanen 2015), and their health.

Differences in needs and behaviours can be identified amongst older age groups. Some changes in travel behaviours can be linked to changed lifestyle factors, such as holding a concessionary bus pass, combined with having different time constraints. Older old groups are more concerned about access to healthcare. Gender has a number of clear and subtle effects linked to car access. Women are still more likely to be reliant on men for car access than vice versa, and are more likely to self-regulate or end their driving careers voluntarily. In terms of driving ability, men's collision rates increase with age, whilst older women are particularly over-represented in collisions arising in challenging circumstances. CAVS might offer the potential to reduce such gender differences whilst enabling safe driving later through the lifecourse.

In general terms rural populations tend to be older than urban ones, and rural living is associated with greater mobility constraints, and often a sharp change in quality of life if car access is lost in a car dependent location. There are some research findings that indicate age-linked trends for residential to more 'multimodal' locations. CAVs might potentially reduce the need for access to mobility to be considered during residential location decisions, or might change the way it is considered.

The potential benefits of CAV could be felt most strongly by those more likely to experience mobility deficits – the older old, older women and those living in more diffuse populations (i.e. rural and suburban locations). These are though potentially also the more vulnerable groups in society, and how CAV might be deployed to support such groups will need to be mindful of this, as it may effect how and where CAV could be used. It is also the case that these groups are not well-represented in research into how such vehicles might be adopted and accepted. Current attitudes amongst younger 'drivers' may also change if they become part of a more vulnerable group in the future.

Older people appear to be willing to engage with technology in vehicles, and to adopt other 'new' means of personal transport where that provides additional mobility, but there needs to be an awareness that not all groups learn or access information in the same way, which may impact on their acceptance of or use of CAV. This may impact on the potential for CAV to provide benefits for older people.

Physical impairment can also impact on drivers both in and out of the car, on the amount, and types of journeys being made, and even on the types of vehicle that older people might drive. Whilst it is possible to compensate for physical impairments in some cases, there are no aids to help those with serious cognitive issues – such as dementia. The future potential of CAV to facilitate mobility in these circumstance could result in a significant increase in vehicle miles travelled, and whilst addressing a social sustainability issue may then impact on an environmental issue.

The coming cohort of older people, the (later) baby boomer generation, expect to continue be mobile, and to be consumers of mobility in later life, with an expectation of continuing to drive (notwithstanding some gender differences). There seems to be little planning though for what might happen if (and when) they can no longer drive. Transport and mobility are not necessarily seen as important issues for the retirement years, and are not necessarily being factored into location

decisions planning either, with evidence that those responsible for transport planning are also giving this less attention than might be necessary. This lack of planning could have both social and economic consequences. Making people aware of the options provided by CAV before they reach a point of not driving might help them adjust to the idea of using them, and to understand how they might provide an alternate means of mobility to maintain lifestyles. Adopting this approach may both smooth and encourage a move away from driving to driverless vehicles, and better engage older people in understanding the potential benefits such a move might bring.

This review has highlighted the importance of out-of-home mobility to older people, and the role that the car plays in providing that mobility at present. There is an acceptance of technological support, but limited enthusiasm (at present) by older people for CAV as a solution to their needs, but at the same time it is possible to see that some groups (women and those in rural communities) will continue to face reduced mobility in later life. Although there is an awareness that for many they will need to reduce, moderate and potentially stop driving, there is little forward planning to cope with this eventuality. It is perhaps then beholden of those that will go on to develop CAV solutions that they also ensure that older people are sufficiently engaged with and considered in the design approach to bridge the current gap between a problem and potential solution.

1 Introduction to the review

1.1 Older people and out-of-home mobility

Even with rising online services and home delivery, access to mobility remains fundamental for inclusion in economy and society, across social groups, and older people are no different in this respect (Parkhurst *et al.*, 2014). What is perhaps unique to this group though is the fact that it is the one demographic that is likely to experience some degree of physical or cognitive decline related to age, a change that may have an impact on their ability to be independently mobile.

For some this may be personal mobility issues, but for many others it might mean the loss (partial or full) of access to a private motor vehicle (or the ability to be a passenger if it is a partner that has traditionally been the driver). Older people in the UK, like the rest of society are increasingly dependent on the private car for the bulk of their out-of-home mobility needs. At present, efforts are made to prolong people's access to a car through the fitting of driver aids, and the increasing availability of driver assistance technologies such as 'self-park' or rear-view cameras. However, with driving cessation (or self-limited reduction) an almost inevitable outcome for most older people, the potential of (connected) autonomous vehicles to help support continued mobility for this group would seem to offer many and significant benefits, and is an area that warrants further investigation in order to ensure that the deployment of such vehicles offers the optimum benefit for all those that might benefit.

1.2 Review topics

Understanding what the impacts are of changes in the ability to engage in out-of-home mobility is a current, ongoing and active area of academic research. Over the last few decades this research has looked at the links between mobility and wellbeing, and mobility and 'exclusion' for older people, with further strands specifically exploring rural and urban issues. This review will draw on the existing wealth of material on mobility and older people as a way of setting a context (but will not set out to repeat the extensive existing literature). It therefore supports the empirical activities of the project in uncovering what the future needs and expectations of older people are in respect of how these new technologies might impact on, and benefit them. Existing, published studies of exposure to the technologies are reported on. Consideration was also given to other groups who might experience some form of mild cognitive or physical limitation that currently limits their ability to access personal mobility either via a car or perhaps public transport. A final area of consideration for this review was to look for any insights that may already be available in respect of how those who are not yet classified as 'older people' might be expecting these technologies to provide a specific solution or resource for them in later life. With various timelines proposed for the more widespread implementation of autonomous vehicles this could mean anyone from 30-60 years' old.

Specifically, the review addressed the following questions as a means of examining the potential future role of connected autonomous vehicles for older people. These questions are:

-
1. What role does mobility, and specifically the use of motorised vehicles such as the private car or public transport have for older people currently?
-

2. Do the 'needs' for mobility differ across the different groups of older people (younger old, older old, non-drivers).
3. What expectations do older people have in respect of new technologies that will automate and connect vehicles?
4. What experience is there of older people making use of existing technologies to provide motorised mobility?
5. What experience is there of older people being exposed to, or trialling connected and/or autonomous vehicles?
6. Are the needs and expectations of others with some form of physical or cognitive impairment similar or different?
7. Have people who are approaching older age expressed opinions about the sort of mobility they would like when they are older?

Each of these 'questions' is reviewed below. Although this review is being undertaken as part of a UK-sponsored research study, it will draw on literature from around the world. The reasons for this are three-fold, firstly that many nations share common experience in respect of mobility and an ageing population, and secondly that research activities related to CAV are taking place in a range of countries looking to exploit such technologies. Finally, UK companies developing CAV technology are seeking to access a global marketplace.

1.2.1 Categorisation of older people

Whilst 'older age' is often seen in a more negative light it is worth noting that older people are not a heterogeneous group, and there will be a wide range of abilities, attitudes and behaviours across people who might range from 60 to 100 and over (increasingly so). As a consequence, research (and policy) often categorises, or groups those in later life via a range of pertinent factors. It can for example be useful to also consider older people and mobility through a lens such as health, with Sixsmith *et al.* (2013 p7) classifying older people into four distinct groups. These groups are: 'Healthy and active seniors', 'People living with chronic disease' and 'People with mild cognitive impairment' and 'People with dementia'. The latter group are beyond the direct scope for this review, as such individuals have not been identified for inclusion in the Flourish research, although it is noted that the possibility for AVs to be used by less able groups such as those with dementia is potentially a key benefit of the technology. For clarity, it is useful to define the difference between those experiencing mild cognitive impairment and those suffering with dementia:

Mild Cognitive Impairment (MCI). A cognitive impairment in at least one aspect of cognitive functioning, but with no sign of dementia and no significant decline in functional activities of daily life (Luis *et al.*, 2003 in Sixsmith *et al.*, 2013 p12). It is suggested that such a condition might affect up to 20% of those aged over 65, and that there is no pharmacological response as such.

Dementia. Primarily an age-related condition, although not part of the normal ageing process, as it will only affect a small proportion of the older population. It is manifest as a severe cognitive decline, with symptoms such as memory impairment, confusion and disorientation, or inability to communicate. It can impact significantly on older people's ability to undertake everyday activities,

and to date the medical and care response has mainly been targeted at helping people to live with the problem(s) (Sixsmith *et al.*, 2013 p11).

Box 1 Comparison of MCI and Dementia

Note: Section 2.6 also briefly considers the problems of demarcating boundaries between those groups experiencing cognitive impairment.

MCI is widely regarded as a transitional syndrome between normal cognitive ageing and clinical dementia, and because older adults with MCI are at risk for dementia, they are also at risk for declines in everyday functioning (O'Connor, *et al.* 2010). There appears to be a continuum of functional loss in MCI, where higher order abilities decline first. These findings suggest that complex aspects of mobility, such as driving and life space², may decline in MCI. The prevalence of MCI as people age, and the greater numbers in the population than those experiencing dementia, for example, makes this an important group (of car users) to consider going forward.

Older people are also commonly categorised into age-related sub-groups to better reflect common characteristics, with those aged variously 75, 80 or 85 and over often termed the 'older-old' (the categorisation here depends on the context, and the author). Such a categorisation can be important in respect of mobility: as people age, so are their travel opportunities (and horizons) likely to diminish – most radically for car users, if and when they lose access to a car.

As well as age and health, a range of other factors such as changing working patterns, access to resources, household and family dynamics might impact on location decisions and activity profiles of older people, and these in turn will also be drivers of, and facilitators of travel and transport.

1.2.2 Flourish research participants

For the purposes of this review, and drawing on health and age-related categorisation, the specific communities being considered in research by the Flourish project are:

- A. **People who are 70 and above now.** It is likely that some members of this group will have age-related physical and/or cognitive impairments that may preclude or inhibit / prevent driving or other forms of mobility / transport. As already noted, those older people who might be experiencing illnesses such as dementia and Alzheimer's disease are not within scope for this work.
- B. **People of any age (over 18), who have physical and/or cognitive impairments** that may preclude or inhibit / prevent driving or other forms of mobility / transport.

Box 2 Flourish target user groups

The primary focus of research activity within Flourish will be to engage with Group A above, and to explore the role of CAV for this section of society. There is, though, an expectation that there will be some commonality of needs and of future CAV-based solutions for this group that will also be relevant

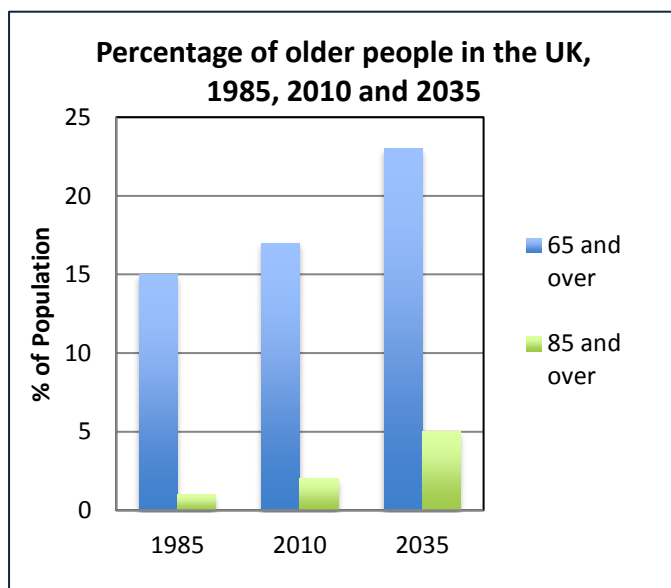
² 'Life space' is a term for the cumulative travel footprint of a person in their daily life. The life space incorporates all the places that someone might go to in order to meet their needs (necessary and discretionary), and understanding these from a spatial (and temporal) perspective can provide a comparative measure of people's engagement with community and society around them.

and pertinent for those in Group B. As a consequence, this review will concentrate on Group A, but be mindful of the potential for wider relevance. It is also the case that to fully embrace literature on all physical and cognitive impairments in relation to out-of-home mobility would be a task beyond the resources that were available for this project.

1.3 Snapshot: Older people in the UK

To further contextualise the current situation, and emerging trends around older people and out-of-home mobility in the UK, the remainder of this section briefly discusses a range of statistical information on older people.

In general, and as a consequence of falling birth rates and a greater life expectancy, the UK population is ageing. Estimates and forecasts from the UK Office for National Statistics (ONS) suggest that the



population of those aged 65 and above was around 11 million in mid-2013 (17.4% of the population) (ONS, 2014a). This was forecast to grow to be around 23% of the population by 2034 (ONS, 2013a). Just over a third of these older people are living alone, the majority of them being single older women – 70% (ibid). Looking at those categorised as older-old, the numbers were around 3 million in 2013, but again predicted to grow significantly over the coming two decades. By 2034 this group could have tripled in size (ONS, 2013b).

Figure 2 ONS 2012. Population Ageing in the United Kingdom, its Constituent Countries and the European Union

An ageing population is also a trend seen across the other countries in Europe. In this context the UK will not be the country with the greatest proportion of older people.

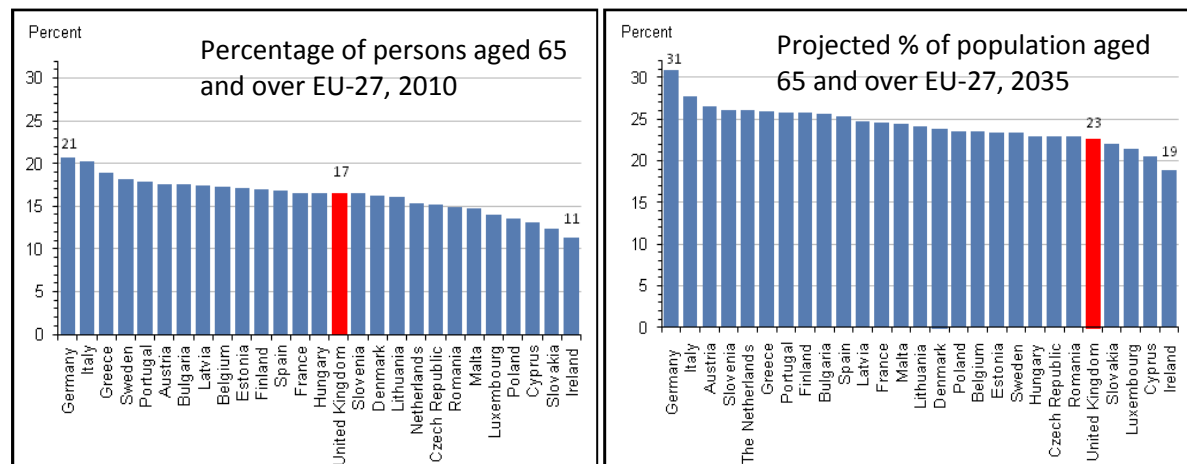


Figure 3 ONS 2012. Population Ageing in the United Kingdom, its Constituent Countries and the European Union

1.3.1 Current travel behaviour of older people in the UK

An indication of the number of journeys older people are making as compared to the rest of the population can be seen in survey results for England in Figure 4,5 and 6 below (DfT 2014).

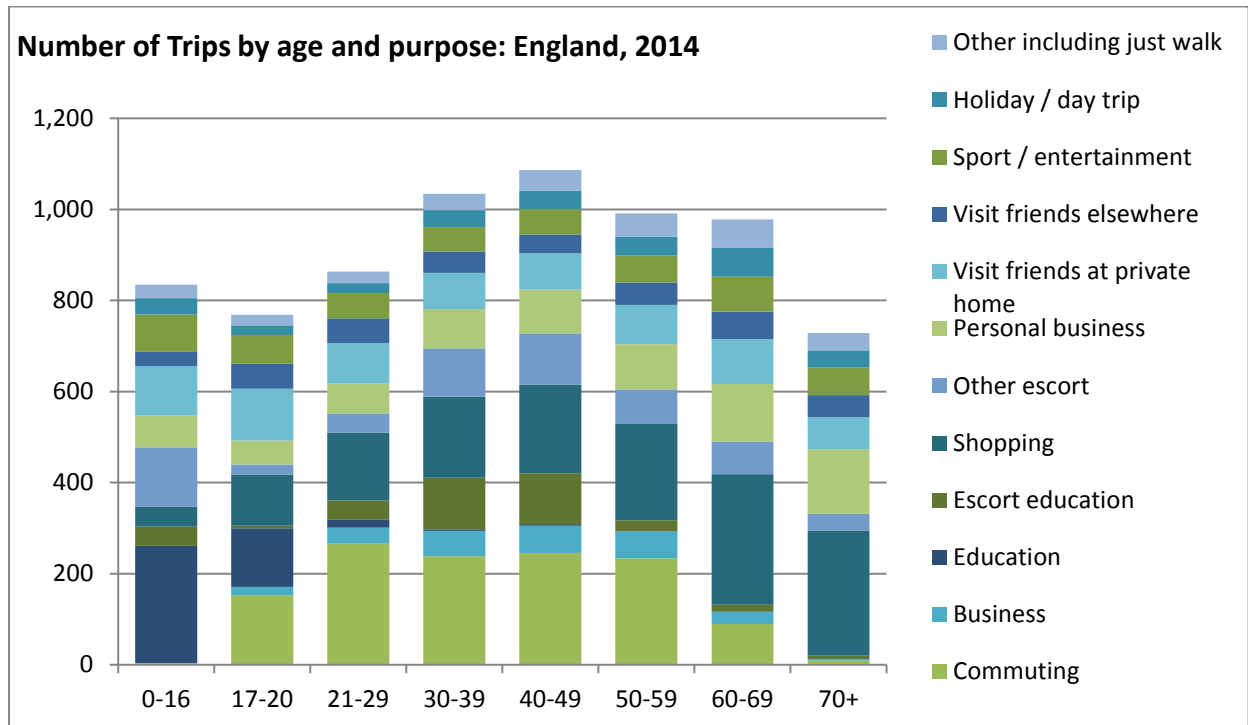


Figure 4 DfT National Travel Survey 2014. [Table NTS0611]

It can be seen that the number of 'trips' made by people begins to decline from around the age of 50, but the most significant decline takes place when people reach their 70s.

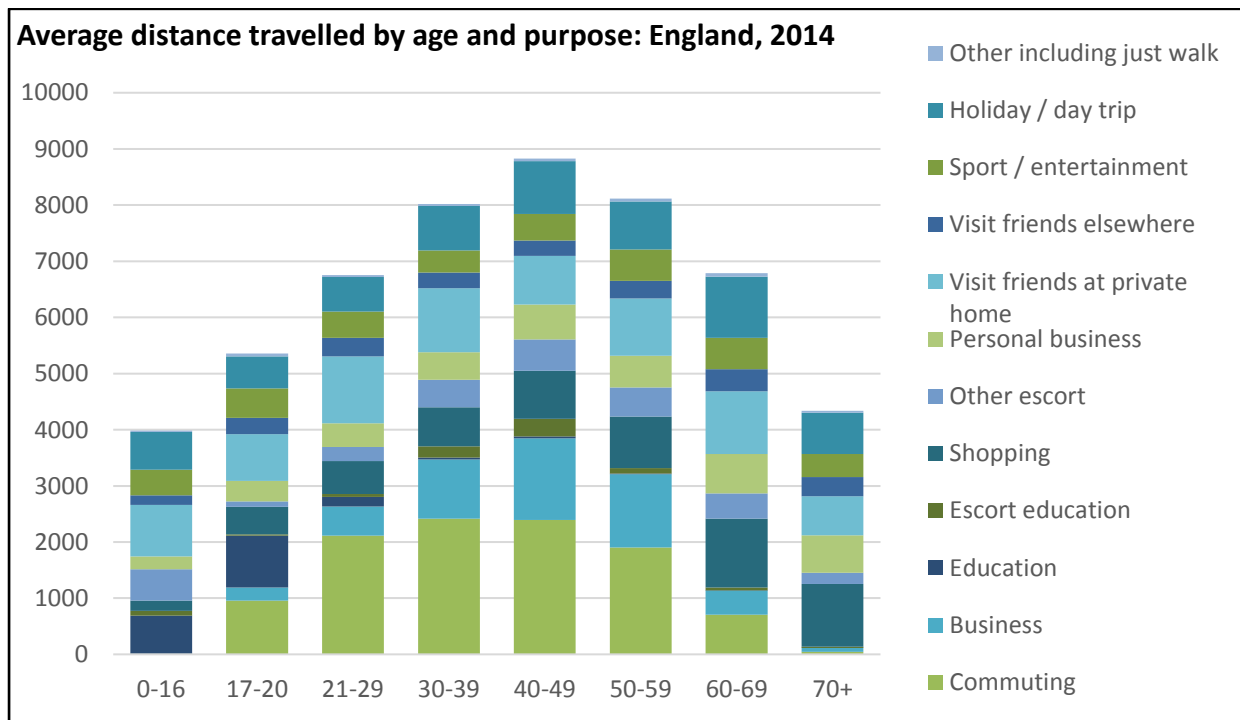


Figure 5 DfT National Travel Survey 2014. [Table NTS0612]

Key points to note for this latter group are the almost complete end of commuting journeys, but an increase in the number of journeys to shop. This is also reflected in distance travelled for different purposes with the 70+ group travelling 1,125 miles/person/year for shopping against an average across all ages of 727 miles/person/year

The importance of the car as a mode of transport can also be seen in the most recent UK data (see Figure 6 below). Whilst those in their 60s broadly maintain the travel profile of earlier cohorts, for those who are 70 and older there is an increase in bus use, and a decrease in walking and cycling.

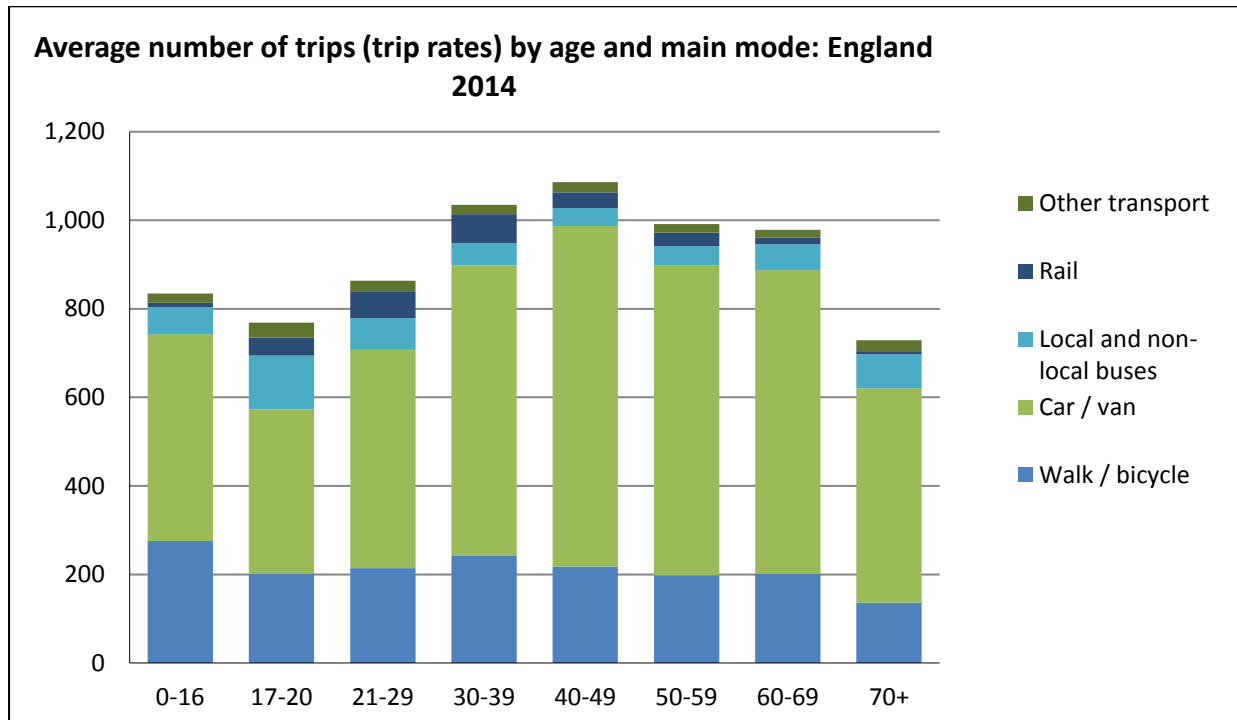


Figure 6 DfT National Travel Survey 2014. [Table NTS0601]

Further observations on older people's travel drawn from the 2014 English National Travel Survey (DfT 2014) include:

- The car remains the mode of choice for older people, clearly evident in Figure 6 above. This is further illustrated by the growth in levels of licence holding for older people, and the continued availability of vehicles in the households of the 'older old' discussed below.
- There is also evidence that older people undertake more of their miles as a passenger than when they were younger (*ibid*).
- Use of public transport, and particularly buses increases for the over 70s, rising from a per person average in England of 331 miles per person per year (pppy) to 529 miles pppy (*ibid*). There is though a decline in rail travel (*ibid*).
- Walking becomes more important component as people get older, but at the same time they walk shorter distances. The national average for England is 187 miles pppy, but for those aged 60-69 it falls to 162 miles pppy, and drops still further for those over 70 to 112 miles pppy (*ibid*).

- Although taxis are used more frequently in older age, they are generally seen as expensive. This is particularly the case in rural areas, although here they may be the only alternative transport available.

1.3.2 Trends in behaviour related to travel and transport

Again referring to data from England, it is possible to see a large increase in the percentage of older people holding a driving licence over the last 40 years. Looking at the data split by gender and age, the increase for older women is particularly dramatic, although it is still the case that fewer women have licences.

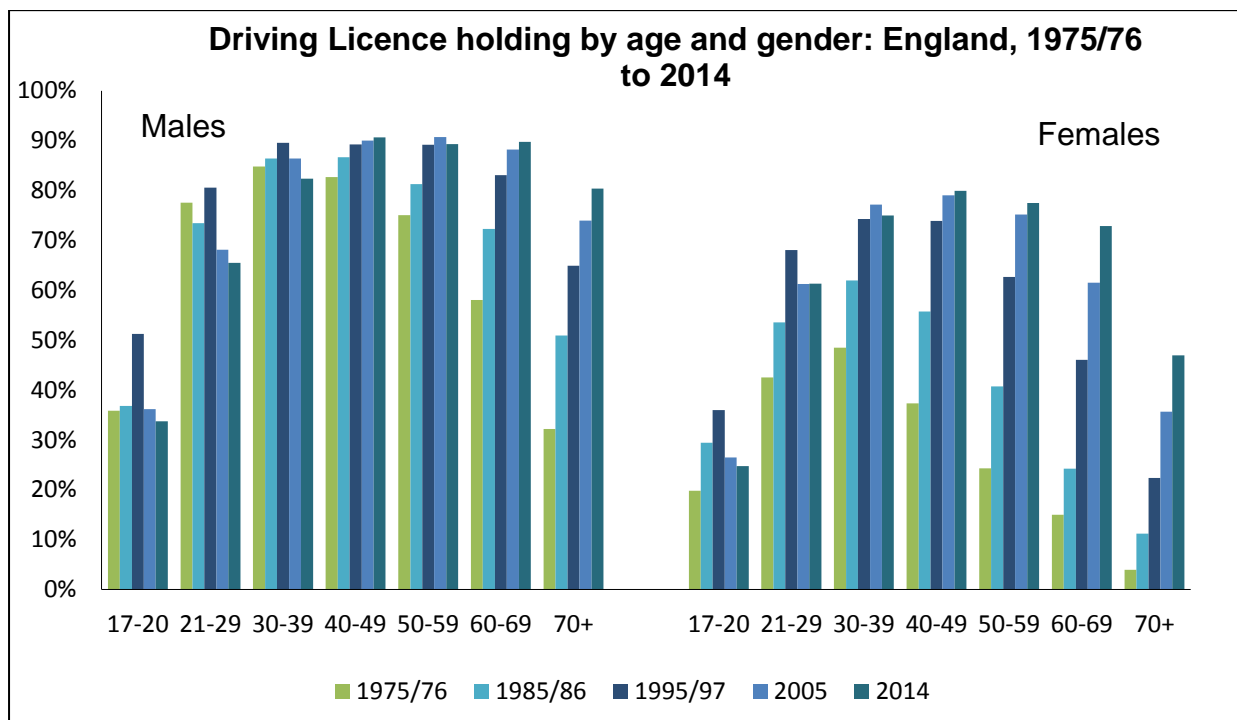


Figure 7 DfT National Travel Survey 2014. [Table NTS0201]

Similar trends have also been seen in other countries. For example, a cohort analysis of National Travel Surveys of Denmark, Norway and Sweden taking a 20-year perspective showed a significant period effect in car ownership and use among older people, with a clear increase during the past 20 years, especially for women (Hjorthol *et al.*, 2010).

Levels of car ownership in the households of older people in England and Wales also reflect the importance of the car for mobility, with more than half of households having access to a vehicle until the 85+ age group (see Fig 8 below).

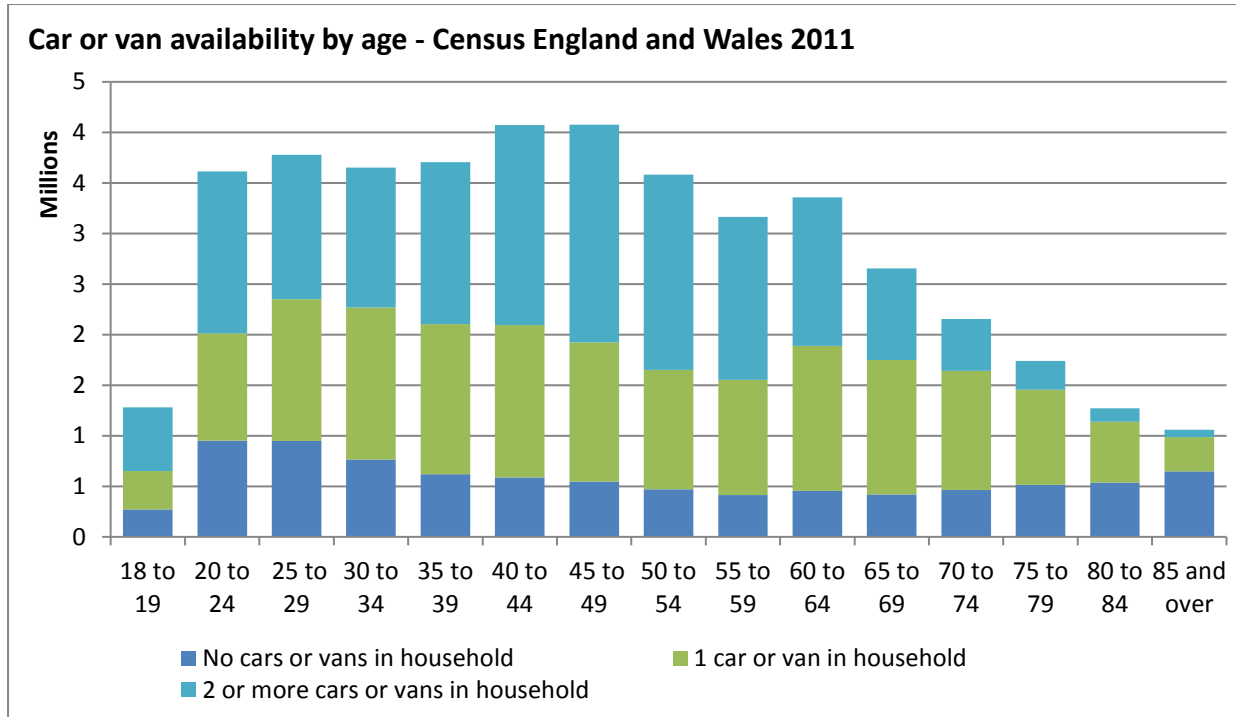


Figure 8 UK Census 2011

Another trend related to use of the car by older people that as people age they tend to drive fewer miles. However, it is noticeable that more recent cohorts of older people are driving more than comparable age groups a few decades ago, making more trips per day, and importantly, engaging in more activity outside of the home (DfT, 2014).

1.3.3 Mobility constraints

When considering older people and their out of home mobility, it is also important to reflect on the personal mobility options or ‘motility capital’ that people may have, as this will impact on their ability to use different modes of transport, or even to potentially walk or cycle to make more localised journeys (Shergold, Parkhurst and Musselwhite, 2012). The UK National Travel survey reports an indication of overall physical mobility abilities for older people. It is clear that constraints increase for the 70+ group, and are more marked for the women in this group than the men.

Table 1 Personal mobility status. DfT National Travel Survey 2014

Mobility status ¹	All aged 16+	16-49	50-59	60-69	70+
All adults (aged 16+):					
With a mobility difficulty	9	3	7	13	32
No mobility difficulty	91	97	93	87	68
Total %	100	100	100	100	100
Males:					
With a mobility difficulty	7	3	6	11	26
No mobility difficulty	93	97	94	89	74
Total %	100	100	100	100	100
Females:					

The mobility of older people, and the future role of Connected Autonomous Vehicles

With a mobility difficulty	11	3	8	16	37
No mobility difficulty	89	97	92	84	63
Total %	100	100	100	100	100

1. The NTS definition of having a mobility difficulty is based on those adults who responded to say they have difficulties travelling on foot, by bus or both. Those that said they only have difficulty getting in / out of a car are classified in this table as having no mobility difficulty.

The same issues also appear to impact on the number of journeys being made per person per year.

Table 2 Number of trips made / personal mobility status. DfT National Travel Survey 2014

Trips made per person per annum					
Mobility status	All aged 16+	16-49	50-59	60-69	70+
With a mobility difficulty	569	729	676	639	454
No mobility difficulty	981	982	1,016	1,029	859

2 Literature review: User needs and experience

2.1 The role of out-of-home mobility, and specifically the use of motorised vehicles such as the private car or public transport, for older people

Whilst it can be argued that mobility is important at all ages, it is increasingly seen as a key factor in facilitating the 'quality of life' experienced by the growing older population (Parkhurst et al., 2014). In particular, the private car, the primary mode of transport for most people in developed countries such as the UK, is critically important (Shergold, Parkhurst & Musselwhite, 2012). As identified in the previous section, the role of the car is only likely to grow, as coming cohorts of older people will have been exposed to, and become accustomed to its use across their whole life courses. The role of mobility for older people, and of the car is explored widely, both in the academic and policy-related literature, in national and international studies, and in the wider work of older people's advocacy groups. Important issues emerging from this literature concern older people's quality of life, their 'wellbeing'³, and their health.

2.1.1 Benefits of out-of-home mobility

Three key areas of benefit for older people from out-of-home mobility were identified in a forward-looking review of older people and mobility undertaken by ILC-UK and Age UK (Holley-Moore & Creighton, 2015). More specifically this reviewed the transport issues facing older people in the UK, utilising data from the English Longitudinal Study of Ageing (ELSA), and a range of stakeholder engagement activities. The study concluded that benefits of mobility could be seen in three important areas: Individual wellbeing, physical health and in interaction with the wider community. In this study, the wellbeing benefits were seen to flow from maintaining contact with friends and family, activities that helped to reduce the risk of isolation and loneliness. The report also noted that older people are also in need of good mobility to possibly go to work or to volunteer (in common with other groups in society) (ibid).

The evidence suggests that more specifically, the use of a car for that mobility is seen as beneficial, helping to reduce the level of 'unmet' activity in a study of older people in Norway (Nordbakke & Schwanen, 2015). The SIZE project, an EU FP7 study, that explored the "*Life quality of senior citizens in relation to mobility conditions*", and found that being able to drive a car supported: independent living, the maintenance of social networks and involvement in leisure activities (SIZE, 2006). Whilst independence is another important benefit of mobility, it is increasingly based on access to a car, as seen in a US study which recorded that older people generally saw themselves as independent, but reliant on the car for this (Wasfi et al., 2012). Older people see car travel as convenient, allowing them to travel when they choose, offering a mode that can involve less walking (an important factor for those older people with limited personal mobility) as well as being the only means of travelling to key services and facilities in some areas (Holley-Moore & Creighton, 2015). Although other modes of

³ In research exploring mobility and older age, the term wellbeing is seen to encompass both the notions of 'happiness' and life satisfaction' as well as the more practical interpretation 'fulfilment of needs' (Nordbakke & Schwanen 2015).

transport may be available to support activities for older people, the car offers more choices of locations where these could happen (Berg *et al.*, 2015), and a direct, door-to-door mode of transport, unlike alternatives such as public transport systems (Bradshaw *et al.*, 2013). In addition, factors such as cars becoming easier to drive are contributing to the fact that ‘seniors’ in countries such as the US are driving cars more than ever before (Alsnih *et al.*, 2003).

The contribution of mobility to wellbeing embraces both ‘utilitarian needs’ such as shopping and healthcare, and ‘discretionary activities’ such as social and family activity, offering benefits through what the authors of a study into this issue in Denmark term as ‘independent separateness’ and ‘sense of community’ (Siren *et al.*, 2015). Social activities can play an important role in response to issues such as loneliness and wellbeing, and mobility can help facilitate these. In a study looking at loneliness with a sample of older people in the Netherlands, results indicate that factors such as being a volunteer and experiencing social interactions have positive effects, and that mobility using a range of travel modes can significantly reduce loneliness (van den Berg *et al.*, 2015). In a US study exploring ‘social connectedness’, it was also seen that older people value mobility, and their ability to have active lives and to make social connections, with these often beyond their immediate neighbourhood as a consequence of being mobile (Yen *et al.*, 2012).

Whilst travelling on public transport is also seen to be beneficial, and can contribute to an individual’s wellbeing (Holley-Moore & Creighton, 2015), a lack of alternatives to the car can be problematic, preventing older people engaging in some activities, maintaining social relations and participating actively in society (Fiedler, 2007). Most public transport options do not offer the (desired) door-to-door functionality of the car and the longer the trip, the more likely a private car will be taken (Bradshaw *et al.*, 2013). Alternatives that provide many of the characteristics of the private car may be preferred instead of public transport, taxis for example allowing an older person to be in charge of their own time (Berg *et al.*, 2015).

As well as the impacts of mobility on individuals, there are also societal benefits, in particular from the economic activities of older people. They are seen to make a net contribution to the economy through expenditure in shops, employment and taxation, voluntary work and by providing childcare (Mackett, 2015). For example, nearly half of older people’s travel is for shopping, and compared with the younger population, shopping tours are more significant for older people (Su & Bell, 2012). It is suggested then that improving mobility for older people would benefit society through increasing economic activity (Fiedler, 2007). Conversely, driving cessation is seen to lead to a significant reduction in overall expenditures as compared to those who were able to continue driving and those economies exposed to this to any great degree risk losing a significant economic contribution (Joseph *et al.*, 2015).

2.1.2 The impacts of reduced mobility

Evidence suggests that a loss of mobility leads to a decreased quality of life and life satisfaction, a loss of autonomy, and even a greater likelihood of illness and increased need for help and care. The SIZE study explored older people’s emotional state through a range of concerns, or ‘fears’ which were seen to negatively impact on quality of life. The survey (across eight countries and over 3,300 older people)

showed that having the ability to use a car could reduce these fears (SIZE, 2006). Again reflecting across a European perspective, Fiedler (2007) makes a link between the need to be mobile and psychological well-being in older age, with reductions in mobility potentially leading to a poorer quality of life, with increased isolation, loneliness and depression. In a US review assessing evidence from research literature on the consequences of driving cessation in older adults, links were made to a variety of health problems, in particular depression and it was noted that driving cessation appeared to hasten the decline across a range of health issues amongst older people (Chihuri, *et al.*, 2015).

Older people are seen to be the most likely to experience mobility deprivation, with many having unmet travel needs (Bradshaw *et al.*, 2013). Focussing specifically on unmet out-of-home activity, a large-scale study of older people in Norway found that those with a driving licence had fewer unmet needs than those who had ceased driving (Nordbakke & Schwanen, 2015). Looking at such issues from an Australian perspective, the Royal Automobile Club of Victoria (RACV) surveyed over two hundred non-drivers in that state, and noted that older people who do not drive may be restricted from participating in a variety of activities, for example social events and visits to family and friends (RACV, 2009). Another Australian study finds that when compared to current drivers, those older people who had ceased driving were less engaged with family and community, spent less time in 'social' leisure activities away from home, and more time on solitary social activities, and in general had a lower level of life satisfaction (Liddle *et al.*, 2012). Other activities that could be affected include volunteering, with those that had ceased to drive spending significantly less time in volunteer work (*ibid*). Some older people may be able to find substitute activities in their own home when they cease driving, but such activities may not offer the physical benefits that work or volunteering might do (Chihuri *et al.*, 2015). This reduced physical activity then potentially accelerating decline in respect of physical (and emotional) health, and in the extreme possibly leading to a need for assistance in the ordinary activities of daily living for some older people (*ibid*). It is important to note though that problems with meeting needs for out of home activity are not purely related to mobility, and that other factors such as health, problems with walking and loss of social contacts can also be contributory factors (Nordbakke & Schwanen, 2015).

Losing out-of-home mobility is a future that most older people are aware of, even if they do not plan for it (Yen *et al.*, 2012, Berg *et al.*, 2015). In their US study, Wasfi *et al.*, (2012) found that although older people reported they were independent now, they knew that the level of mobility they had was 'not permanent', and that they would need to find out about alternatives at some point. The particular importance of driving a car as a means of transport is illustrated by the observation that when older people lose access to a car this is seen as a major life event, a '*tangible outcome of ageing*' (Ziegler & Schwanen, 2011).

2.1.3 Conclusions

Links have been made for the benefits that the ability to undertake out-of-home mobility provides in respect of wellbeing and health for older people. It is also apparent that access to a car can be particularly beneficial in this respect, and losing such access can lead to problems (including mental and physical health issues). It is a situation that many people are aware of happening, but that few adequately prepare for. This suggests that the adoption of CAV in the future could offer a new set of

The mobility of older people, and the future role of Connected Autonomous Vehicles

choices for those experiencing reduced mobility through driving cessation, and that CAV may find a ready purpose in providing such mobility solutions.

2.2 Variation in mobility needs across different groups of older people

The term 'Older people' can cover anyone from 60-100 and above, and embraces a broad spectrum of capabilities and needs. As such it is a single name for a very heterogeneous group of people, who may have differing mobility needs. In an attempt to delineate some of these differences, this section will consider the needs of older people broken down by age (younger old and older old), by gender, and by location (rural / urban / suburban). Consideration will also be given to levels of access to a car, including those who maintain their access to a car, but self-regulate use and those who have given up driving for instance. It is likely that in reality an older person will inhabit a number of these categories (e.g. female, rural dwelling younger old), and will present a composite set of needs.

2.2.1 Age

In respect of a range of metrics, such as the number of journeys made each day, distance travelled, and complexity of journeys, these will in general decrease with increasing age (Truong & Somenahalli, 2011). It is also the case that as people reach later life so they experience a reduction in participation in activities, and a shrinking in their 'activity space' (the area they travel over to undertake activity) (Ahern & Hine, 2012). There are though more substantial differences seen between the younger old and older old. In part this reflects other factors affected by physical ageing such as health. For example, in a US study exploring the role of age in determining travel needs for older people (Alsnih et al, 2003), the distinction between the younger old (aged 65–75 years) and the older old (those aged over 75 years) was seen to be particularly useful, denoting a 'threshold of health change' that would be important in respect of mobility needs.

Younger old

Trips for shopping, leisure and social activities continue to be as common as before in age groups near retirement age (Heikkinen & Henriksson, 2013), and the importance of the car does not change for those recently retired (Berg et al, 2015), or seen as the 'younger elderly' (Alsnih *et al.*, 2003). In this latter work considering US 'seniors' aged 65 – 75, travel behaviours are seen to reflect those aged 18 – 59, with the preferred mode of transport still being the car, and travel patterns not significantly different to this younger group (*ibid*). One area of difference though is that many journeys made by this group are short (Alsnih *et al.*, 2003, Berg *et al.*, 2015). Although the car was used more than other transport modes, having the time to walk and cycle now was also highly valued by a sample of 61 – 67 year olds in Sweden (Berg *et al.*, 2015).

Older old

One particular concern for those seen as the older old is in access to healthcare services. In a UK context for example, those most likely to be experiencing difficulties in accessing their GP surgery have an average age of 80, with poor health and lower incomes (Holley-Moore & Creighton, 2015).

In the US, those aged 75 and over are a group likely to have lower income, lower car ownership and poorer health, and be more reliant on other means of mobility such as public transport (Alsnih et al, 2003). Alternatives to the car may not always be an option, with personal mobility and health issues preventing use for some aged over 80, and those with longstanding illnesses seen to be the least likely to use public transport (Holley-Moore & Creighton, 2015).

2.2.2 Gender

While older women are more likely to travel by public transport and by car as passenger, older men tend to travel by car as driver (Truong & Somenahalli, 2011). In fact, in their exploration of UK data, Li *et al.*, (2012) identify that women over 70 are very reliant on males to drive them. Notwithstanding this, driving licence holding amongst older women in the UK is increasing dramatically (ibid). Although women live on average longer than men, US data suggests that older women have a higher disability rate (Alsnih *et al.*, 2003).

Alternatives to the car

Older women will be negatively burdened by a lack of transportation alternatives (ibid) and differences between men and women also emerge in respect of the use of these alternatives to the car. For example, a study exploring attitudes of older people in Scotland suggests that there are few obstacles to public transport use, particularly for older women, with agreement that bus travel is good, but convenience still leading people to prefer cars (Li *et al.*, 2012). Community transport is another potential alternative, but in an Irish context this was seen to offer trips and services that were more attractive to women (Ahern & Hine, 2012) and thus less likely to be used by men. Other research has found more positive responses in respect of the use of alternatives to the car. For example, in a series of focus groups in Norway which examined travel needs, travel practices and activity participation of older women in an urban setting, it was found that with sufficient experience with alternatives, a good-quality transport system, and activities in suitable locations then women were not reliant on men to drive them (Nordbakke, 2013). The same study also suggested that older women may respond to not being able to drive by instead actively managing opportunities and their capabilities to engage with alternate mobility (ibid).

Gender may also impact on the types of journey made. Focusing on a London (UK) area travel survey in which over 6,400 over 65s made at least one trip on the survey day it appears that women are engaging in more complex trips (Su & Bell, 2012). Similarly, when looking at shopping in the same data, men were found to be less likely to generate complicated shopping tours. When they need to shop, then a simpler approach is preferred (ibid).

Self-regulation and driving cessation

In a study involving focus groups and a survey in the US, even the youngest (older) women perceived themselves to be limiting their driving more than men of a similar age were, and at the same time their confidence levels in their driving skills were also lower (D'Ambrosio *et al.*, 2008). This attributed to gender, age and health factors. The one exception to this finding being women who lived alone, who were less likely to self-regulate and more likely to report higher confidence in their driving abilities. Similar results were seen in Australia, where research found that men were reporting less self-regulation than women in respect of a number of driving situations, at night, in bad weather, in unfamiliar areas, on motorways and combinations of these, as well as reversing their vehicle (Molnar *et al.*, 2012). Different patterns are seen between men and women, with a US study finding that differences in driving cessation patterns among men and women reflected patterns of self-regulation amongst older drivers (D'Ambrosio *et al.*, 2008). Drawing on a series of focus groups in Ireland, it is suggested that because men tend to live a more car-dependent lifestyle through their adult lives they

are less prepared for life without a car than older women (Ahern & Hine, 2012). Older women can though be seriously impacted by loss of a spouse, as many of them would not be able to drive themselves but had always had a husband who would drive for them (ibid).

Collisions

Gender differences have also been highlighted in respect of collisions. In particular, higher serious collision rates for men, and over representation of older women in collisions in a range of 'poor' driving conditions and more complicated situations (cited as: turning right and negotiating roundabouts, crossroads and a range of more complicated junctions) (Li *et al.*, 2012).

2.2.3 Location

There are two aspects of this factor to consider, firstly whether the type of settlement that older people are living in has an effect on their mobility needs, and secondly if changing location impacts on older people's travel needs and choices. This latter approach being seen as an 'important tool' for older people in respect of accessing resources, including mobility (Alsnih *et al.*, 2003). In an Australian context (Adelaide), health facilities, shopping and public transport services were reported as being the three most important influences on location choices of older people, although the need to move to access smaller living accommodation in older age can also be important (Truong & Somenahalli, 2011). As a consequence, in this study a trend of moving from the outer suburbs to those described as middle and inner was then evident (ibid).

Residential location

Rural populations are seen to age faster than urban populations, whilst the primary mode of transport for such areas is the car, with public transport availability and use much lower than in urban areas across all age groups (Holley-Moore & Creighton, 2015). Public transport availability is unlikely to change as low population density in these areas makes it more difficult to provide regular, cost-effective services, a situation not helped by recent economic austerity measures in many rural locations, notably local authority spending cuts on transport services. All of these factors can make living in a rural area more challenging for older people (particularly those without access to a car. In a study of such circumstances in Ireland, an 'extremely negative impact' on the quality of lives of older people is identified following driving cessation, primarily as a consequence of their being few alternatives to the car available in such areas (Ahern & Hine, 2012).

Research indicates car dependence can be particularly detrimental in suburban environments where in the case of the US most older adults reside, and which often lack alternative transportation options (Pape *et al.*, 2014). Not only this, but these areas may also have limited pedestrian facilities such as 'sidewalks' or street lighting (Coughlin, 2009, Pape *et al.*, 2014). This lack of alternatives, combined with an 'apprehensive attitude' towards public transit, can mean that those who have stopped driving may find themselves 'stranded' and 'unable to meet daily needs' (Pape *et al.*, 2014).

As a consequence of these issues, suburbs have been shown to increase the isolation or mobility deficiencies of those older adults unable to drive (Coughlin, 2009). Conversely, for those living in more urban settings, there is likely to be more choice of alternatives to the car. In these circumstances, a

decision to not use public transport may be an individual choice because older people would prefer to walk. (Holley-Moore & Creighton, 2015).

2.2.4 Access to a car

Access to a car may be restricted for those who are self-regulating their driving, or they may cease to drive altogether for a variety of reasons (health, finance etc.). Both instances will have some impact on the individual's ability to meet their mobility needs compared to those who maintain uncompromised access. There are some nuances in these conditions though that may impact on how different older people may experience different outcomes. These factors are highlighted by two studies exploring these specific topics.

In respect of self-regulation, a study exploring data on older Australian and Canadian drivers, Molnar *et al.*, (2013) identifies that this concept is actually manifest on several levels. These are: tactical, strategic, and life-goal related self-regulation. Respectively, these relate to actual driving practice (for example distance between vehicles), decisions about whether to make a journey at that time on that route, and in relation to location choices which will impact on journey destinations.

A Danish study (Haustein & Siren, 2014) that looked more closely at driving cessation drew a number of conclusions. That giving up your driver's licence (or never having had one) significantly affected unmet mobility needs, and in particular journeys to visit friends were impacted. In addition, for those with poor health, the loss of a licence seemed to be less of a barrier in respect of access to shopping (a necessary journey), but was important in respect of leisure-related trips (discretionary travel perhaps). It was also concluded that those older people in the study who had experience of, and access to alternative modes of travel still couldn't sufficiently compensate for mobility problems due to not being able to drive (*ibid*).

2.2.5 Conclusions

It is clear that the group referred to as 'older people' do not exhibit a single homogenous set of out-of-home mobility demands. Differences are seen as a result of age, gender, and location, and the ability to address these needs is also greatly impacted by the level of access to a car (for most older people). In respect of the journey purpose and function, it also appears to be the case that in broad terms it is the 'discretionary' travel that is more likely to be unmet as older people age, or where circumstances limit access to mobility choices. It is also evident that in the earlier stages of later life travel behaviours in the main continue existing behaviours, with a focus on the use of a car, and that it is as people age and become more likely to encounter health constraints that the focus of travel might change (more need for access to healthcare for example), and choices become more constrained. Older old females (and particularly those in rural areas) without access to a car would seem likely to be the sub-group with potentially the greatest number of unmet needs.

Whilst CAV have the potential to provide a mobility resource for all older people, it is clear that the benefits could be felt even more strongly by those most likely to experience mobility deficits – the older old, older women (especially those who outlive their spouse), and those living in more diffuse populations (i.e. rural and suburban locations). Whilst CAV could offer them a new solution to support out-of-home mobility, this should be seen in the context that these are potentially also the more

The mobility of older people, and the future role of Connected Autonomous Vehicles

vulnerable groups in society, and deployment of CAV to support such groups will have to take account of this. This may have implications for the type of services that use CAV, the way that they operate and how they interact with occupants.

2.3 Expectations of older people in respect of new technologies that will automate and connect vehicles

2.3.1 General opinions and willingness to use CAV

A small number of studies have researched the views towards CAV, and have found that older people are less likely to embrace driverless cars than younger adults. However, this research is sparse and only provides high-level findings, mainly from online surveys of the general population with analysis breakdown by age, without any further exploration of the underlying reasons as to why older people are less likely to embrace driverless technology. Here it is important to note, also, that public awareness of CAVs is generally not highly developed, and is probably not evenly developed across the population. The attitudinal findings may as much be reflecting uncertainties about CAVs, as much as resistance to them.

A survey by Ipsos MORI (Misell, 2014) explored opinions of driverless cars among 1001 British people between the ages of 16 and 75. Results showed that 18% of respondents found it important that car manufacturers focus on driverless technologies. The study analysed responses according to age groups and found that older people are less likely to embrace the concept of driverless cars (see Figure 8 below).

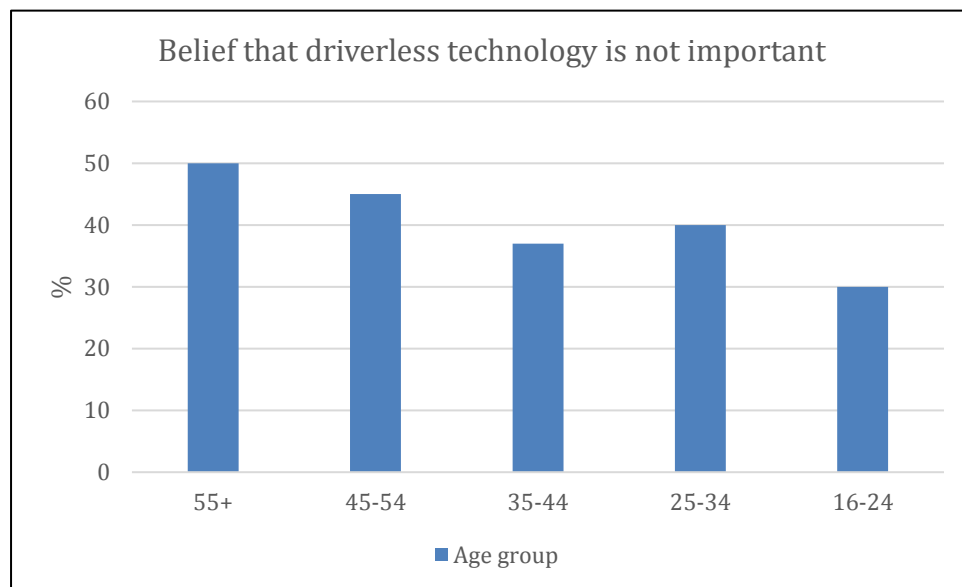


Figure 9 Opinions of driverless technology. Source: Ipsos Mori

The results show a difference between older respondents and the younger people in the survey. Results of the study also showed that men were more in favour of driverless technology compared to woman, as did those who live in congested cities compared to respondents who live in a non-urban environment.

Bansal & Kockelman (2016) analysed the results of 1,088 American people aged between 21 and 69 who responded to a survey exploring opinions regarding driverless cars and used an interval regression model to estimate willingness to pay for adding connectivity and different levels of automation. Interestingly, the study indicated that more experienced licensed drivers were more willing to pay to add connectivity to their current and existing vehicle but older people (over the age

of 54) were less willing to pay for automation, placing lower value on automation technologies than younger adults. The authors suggest that these findings may be because older individuals find it difficult to conceive that CAVs will soon be widespread on roads. Results also indicated that adoption of autonomous vehicles by older people in the future may be more dependent on friends' adoption rates.

In another study, Bansal *et al.*, (2016) surveyed 347 adults between the ages of 21 and 70 living in Austin, Texas about CAV and shared autonomous vehicles (SAVs) - car-sharing through the use of CAV. Older licensed drivers expressed less interest in such technologies, although the age of 'older' drivers was not stated. The authors suggested that older drivers may be concerned about having to learn how to use CAV and SAV and that they do not trust these technologies. They may also not want to lose the pleasure of driving. Older people were predicted to have a significantly lower willingness to pay for AVs and were predicted to use SAVs less frequently.

Other research has assessed willingness to pay for driverless cars. Payre *et al.*, (2014) used an online questionnaire to examine the attitudes and a priori acceptability of fully automated driving technology among 421 French drivers aged between 19 and 73. Older people seemed less likely to pay for this type of technology, however age groups were not clarified. Men were also more willing to use a fully automated vehicle compared to women and indicated that they were more inclined to purchase one. Abraham *et al.*, (2016) performed a correlation analysis with results showing that older adults in the US were less willing to pay more for a self-driving car and were less comfortable with higher levels of automation, but the age of 'older' adults was not stated. Kyriakidis *et al.*, (2015), on the other hand, analysed results from an online survey of 5,000 respondents across 109 countries and found no strong effect of age on willingness to pay for automation.

A study of 302 drivers in the US aged 50-69 by The Hartford Center for Mature Market Excellence and the MIT AgeLab (2015) found that older drivers are more interested in "test-driving" a driverless car than in purchasing one. Almost three-quarters (70%) of participants said they would test-drive a self-driving car, however if a self-driving car and a "regular" car were the same price, only 31% would purchase the self-driving car and 39% would purchase the "regular" car. The fact that 31% were unsure which car they would purchase suggested there is uncertainty regarding driverless cars among older drivers.

In a survey of 1,533 respondents aged 18+ in the US, UK and Australia, Schoettle & Sivak (2014) found that older respondents (no clarification of age groups) were less interested in having self-driving technology and less willing to ride in self-driving vehicles. Older respondents were also less optimistic about the potential benefits of these technologies. They were less optimistic that self-driving vehicles would reduce traffic congestion, shorten travel times, and lower insurance rates, and overall were more concerned about self-driving vehicles.

A more recent survey by Schoettle & Sivak (2015) of 505 licensed drivers in the US also found that older respondents are more concerned about riding in completely self-driving vehicles compared to younger respondents. As shown in Table 3 below, 41.2% of respondents aged 60 and older were 'very concerned' compared to 21.0% of respondents aged 18-29, and only 5.1% of respondents aged 60 and older were 'not at all concerned' compared to 15.8% of those aged 18-29. Slight differences were also

observed between older drivers (60+) and those aged 45-59. The levels of concern for riding in completely self-driving vehicles in this survey were similar to those found in the previous survey (Schoettle & Sivak, 2014).

Table 3. Responses to question: "If the only vehicles available were completely self-driving, how concerned would you be about riding in such vehicles?" [Table 3, Schoettle and Sivak 2015]

Question: "If the only vehicles available were completely self-driving, how concerned would you be about riding in such vehicle?"					
Response	Age				
	18-29	30-44	45-59	60+	Total
Very concerned	21.0%	36.7%	40.3%	41.2%	35.6%
Moderately concerned	41.9%	25.8%	29.2%	35.3%	32.7%
Slightly concerned	21.9%	21.7%	21.5%	18.4%	20.8%
Not at all concerned	15.2%	15.8%	9.0%	5.1%	10.9%

Seapine Software's (2014) survey of 2038 respondents in the US highlighted small age differences about concern riding in AVs. They report that approximately 88% of all respondents were concerned about riding in AVs: 84% among those aged 18–34 year-olds and 93% among those aged 65 years and older. Among all respondents, 79% were concerned about AV equipment failure, 59% were concerned about liability issues, and 52% were concerned about hacking of AVs information systems, although differences between the age groups were not reported.

2.3.2 Comfort with levels of vehicle automation

Research has explored older people's comfort with different levels of vehicle automation. A very small number of studies have suggested that older people are comfortable with features that may provide some sort of assistance and safety whilst driving, however they are hesitant to the concept of fully autonomous vehicles and have expressed that they would still like to be able to take control of the vehicle.

Davern *et al.*, (2015) carried out an online survey of 1,070 older drivers aged 60+ and 8 in-depth interviews with older drivers in Australia. Participants generally had very poor knowledge and awareness of various new safety technologies, e.g. blind spot warning and lane departure warning, yet they were open to the idea of having in-vehicle safety technologies and reported that they would feel safer if these technologies were present in their car. However, participants were less open to the idea of autonomous vehicles, as they believed that safety features and technologies should be there as a 'just in case' measure instead of replacing driver skill. Many participants were opposed to too much reliance on technology to do the driving.

Adding to findings from Davern *et al.*, (2015), there is research to suggest that older people are less open to the idea of autonomous vehicles than younger adults. In their survey of 505 licensed drivers in the US, Schoettle & Sivak (2015) asked about the level of vehicle automation that respondents preferred, with the option being: no self-driving, partially self-driving, and completely self-driving. As shown below in Table 4, preference for having vehicle automation generally decreased as respondent age increased. Half (50%) of respondents aged 60+ preferred no self-driving compared to 35% of those aged 18-29, and only 11% of respondents over the age of 60 preferred completely self-driving. Slight

differences were also observed when comparing older drivers (60+) with those aged 45-59. Additionally, respondents expressed a preference for retaining some control of self-driving vehicles. Nearly all respondents said they would want to have a steering wheel available in completely self-driving vehicles as well as gas and brake pedals. All respondents had this preference, with no meaningful age difference observed.

Table 4. Responses to question: “Vehicle manufacturers are considering using one of three levels of automation in future vehicles. Which level would you prefer to have in your personal vehicle?” [Table 2, Schoettle and Sivak 2015]

Response	Age				
	18-29	30-44	45-59	60+	Total
No self-driving	35.2%	37.5%	49.3%	50.0%	43.8%
Partially self-driving	47.6%	41.7%	36.1%	39.0%	40.6%
Completely self-driving	17.1%	20.8%	14.6%	11.0%	15.6%

The findings about aged differences with regards to preference for full automation were further supported by Abraham et al. (2016). In their survey of 2954 adults in the US, there was a statistically significant correlation between age and preference for full automation; older respondents were generally less comfortable with the idea of self-driving cars compared to the younger respondents. As shown in Table 5 below, only 12.7% of respondents aged 75+ said the maximum level of automation they would be comfortable with is full autonomy compared to 40.0% of respondents aged 25-34.

Table 5. Age differences in willingness to use automation in vehicles: maximum level of automation [Table 3, Abraham et al. 2016]

Level of automation	Age						
	16-24	25-34	35-44	45-54	55-64	65-74	75+
No Automation*	12.4%	8.0%	9.7%	6.1%	5.0%	3.8%	3.1%
Emergency Only	18.3%	11.3%	15.7%	16.0%	14.7%	12.2%	16.7%
Help Driver*	26.7%	25.4%	21.1%	41.2%	44.4%	56.0%	52.2%
Partial Autonomy	16.3%	15.3%	19.0%	13.2%	17.0%	13.9%	15.4%
Full Autonomy*	26.2%	40.0%	34.4%	23.4%	18.9%	14.2%	12.7%

* Age differences significant at $\alpha=0.05$

However, fewer older respondents wanted no automation at all and a larger proportion were comfortable with active assist features that help the driver while the driver remains in control. As shown in Table 6, older adults were more comfortable with automation features that reduce the potential/severity of collision and are slightly more comfortable with features that help with steering, but are far less comfortable with giving up control of driving.

Table 6. Age differences in willingness to use automation in vehicles: automation features/types [Table 4, Abraham et al. 2016]

Automation features that...	Age						
	16-24	25-34	35-44	45-54	55-64	65-74	75+
...reduce potential/severity of collision*	72.8%	78.9%	79.5%	82.4%	85.4%	90.3%	89.0%
...help with speed control	56.4%	69.2%	66.5%	60.1%	64.8%	62.8%	61.8%

...help with steering	48.0 %	58.3 %	56.8 %	57.0 %	61.0 %	62.9 %	60.1 %
...periodically take control of driving*	55.0 %	61.0 %	55.9 %	44.8 %	47.3 %	38.1 %	38.6 %

* Age differences significant at $\alpha=0.05$

Overall, the surveys by Davern *et al.*, (2015), Schoettle & Sivak (2015), and Abraham *et al.*, (2016) suggest that older adults are comfortable with some types of features and technological innovations that help the driver, but show hesitation around full automation and giving up control of driving. However, the underlying reasons behind these age differences were not explored and this is an area for future research to address.

2.3.3 Attitudes and preferences towards in-vehicle technologies

In addition to preference for automation, research has aimed to explore preference towards different types of in-vehicle technologies.

Smith *et al.*, (2014) held focus groups in the US with two age groups of older drivers, those aged 55-64 and those aged 65-75, to assess their acceptance of four different in-vehicle systems: night vision, blind spot detection, forward collision warning, and intersection navigation. Overall, the younger age groups of older drivers were more trusting of the various safety systems and felt that more drivers their age would want the various systems compared to the older age group. In contrast, the 65-75 year olds were less anxious and less concerned about becoming overly reliant on the different systems compared to the 55-64 year olds. Data from the focus groups were used to create a matrix to rate the benefits of different in-vehicle safety systems. In-vehicle systems that alert drivers to potential hazards (e.g., a forward collision warning system) resulted in the highest rating while systems that facilitated a driver's ability to control the vehicle (e.g., an anti-lock braking system) had the lowest rating. In conclusion, older drivers appeared to be more open to the idea of systems that will provide safety measures and facilitate their ability to drive, but are not ready to give up control of the vehicle.

These findings are supported by research from The Hartford Center for Mature Market Excellence and the MIT AgeLab (2015) who explored the likeliness of 302 older drivers aged 50-69 in the US to adopt 7 different in-vehicle technologies. In their study, the older drivers were most willing to adopt blind-spot warning systems followed by reverse back-up cameras, smart headlights, collision avoidance systems, and lane departure warning systems. Older drivers were open to the idea of using in-vehicle technologies as 96% of participants said they were willing to buy a car with at least one of the seven in-vehicle technologies, and they believed that the primary benefit of these technologies was to improve safety for the driver. However, only 10% indicated that they would be willing to buy a car with all seven technologies. Similar to the findings from Davern *et al.*, (2015), some participants were worried that other technologies, such as parking assistance (42% of participants) and adaptive cruise control (25% of participants) might make drivers too reliant on these technologies. This was a follow-up of a 2014 study of 927 drivers aged 50+ (The Hartford Center for Mature Market Excellence and MIT AgeLab, 2014). In this earlier study, the top in-vehicle technology for older drivers was blind spot warning systems followed by crash mitigation systems, emergency response systems, drowsy driver alerts, and reverse monitoring systems. Over half (51%) said they would feel safer if their vehicle had

all of the most up-to-date technologies. Interestingly, women aged 50 plus were more likely than men to report that having all 10 technologies would make them feel safer.

2.3.4 Conclusions

What emerges from the studies above is that older people are open to the idea of in-vehicle safety technologies but less so for technologies that can take over the control of driving and which drivers may become too reliant on, supporting the findings above that older people are less comfortable with the concept of autonomous cars. It must be noted, however, that many of the studies reviewed here involved older drivers predominantly in their 50s and 60s, and little research has explored older drivers who are aged 70 and above.

There is limited evidence here directly from groups identified as particularly vulnerable to mobility deficits (the older old, older women, non-drivers for example) as to their views on CAV. It may be that views on the applicability of driverless technologies may be different within these constituencies, or indeed that the views of the younger drivers seen in many of these surveys may also change over time – or as the technology becomes more prevalent. The fact that Flourish itself intends to focus on those aged 70+ will provide additional insights into the views of this group.

2.4 Experience of older people making use of existing in vehicle technologies and technologies that provide motorised mobility

This section starts by discussing the experience of older people making use of technologies that are commonly found in vehicles, and then goes on to discuss technologies that provide motorised mobility, such as mobility scooters and electric bicycles.

2.4.1 Use and benefits of in-vehicle technologies

As discussed in section 2.3 above, older people are open to the idea of using in-vehicle technologies, particularly those that provide some added level of safety. Evidence also suggests that older people are actually using them and benefit from them.

Eby *et al.*, (2015) conducted a systematic review to synthesize the knowledge about older drivers and advanced in-vehicle technologies, focusing on use, perception, and outcomes. They reviewed 16 technologies which were grouped into 3 categories: crash avoidance systems (e.g. forward collision warning and parking assistance), in-vehicle information systems (e.g. navigation assistance), and other systems such as cruise control. The 16 technologies were then scored according to their overall value for older drivers, taking into account use, perceptions, and outcomes. An overview of use of the technologies which scored ‘high’ value for older drivers are summarised in table 7 below.

Table 7. Use, perception, and outcomes of in-vehicle technologies scored ‘high’ value for older drivers [Table 2, Eby *et al.*, 2015]

Technology	Use	Perception	Outcomes
Forward Collision Warning/ Mitigation	<ul style="list-style-type: none"> Nearly all always keep the system on Older drivers pick longer headways 	<ul style="list-style-type: none"> System rated positively Some concerns about false alarms 	<ul style="list-style-type: none"> Faster reaction times to forward threats Potential crash reduction of up to 20% Helps prevent crashes Little negative behaviour adaptation
Parking Assist: rear-view display	<ul style="list-style-type: none"> Most always keep system on 10-14% of glances go to rear-view display while backing Warnings received at least once per week 	<ul style="list-style-type: none"> 95% want system in next vehicle 30% report frequently unnecessary False alerts when there is nothing behind vehicle 	<ul style="list-style-type: none"> Helps drivers notice obstacles behind them Improves ability to fit squarely in parking spaces 55% reported system relieves stress Combining backup video display with obstacle detection warnings enhances benefit
Parking Assist: cross traffic warning	<ul style="list-style-type: none"> All turn system on All experience alerts 	<ul style="list-style-type: none"> Considered useful Up to one-third report unnecessary alerts, mostly in bad weather or 	<ul style="list-style-type: none"> Helps prevent collisions when backing up

The mobility of older people, and the future role of Connected Autonomous Vehicles

		<ul style="list-style-type: none"> with stationary objects off to the side Up to 15% report failed alerts at least once, when another vehicle is approaching from behind very quickly 	<ul style="list-style-type: none"> No changes in backing up behaviours
Parking Assist: semiautonomous parking assistance	<ul style="list-style-type: none"> No information identified in literature 	<ul style="list-style-type: none"> Positive ratings 	<ul style="list-style-type: none"> Reduced mental workload Reduced stress Improved parking behaviour Improved parking without the system
Navigation Assistance	<ul style="list-style-type: none"> Frequent use Take longer and have more difficulty than younger drivers learning to use system Have more difficulty than younger drivers reading displays More frequently use system with a "co-navigator" passenger 	<ul style="list-style-type: none"> Highly regarded 	<ul style="list-style-type: none"> Helpful in wayfinding More frequent travel during times and on roadways that would normally be avoided Increased feelings of safety, confidence, attentiveness, and relaxation Only minimal distraction reported
Automatic Crash Notification	<ul style="list-style-type: none"> Does not require user input 	<ul style="list-style-type: none"> No information identified in literature 	<ul style="list-style-type: none"> High potential for fatal crash reduction

The review concluded that advanced in-vehicle technologies can help extend the period over which an older adult can drive safely. Benefits of these technologies include help to avoid crashes, greater confidence on the road, improved ease of driving as well as comfort, and helping older drivers travel where or when they may not normally do so. Studies showed that older drivers use many of these technologies frequently and rate them highly however older drivers may use some technologies differently to younger drivers.

For example, Emmerson *et al.*, (2013) conducted focus groups in the US with older drivers aged 60-86 to explore the use of in-vehicle navigation systems among this age group. The study identified broad differences in older people’s technological ability and their ability to understand and alter settings for their in-vehicle navigation systems. Many older adults were shown to have limited understanding of their in-vehicle navigation systems beyond the default setup and were unable to fully utilise this technology. The study concluded that older drivers are aware of how technology can assist them in their navigational needs, but that *‘the current [in-vehicle navigation systems] approach to journey planning and information delivery, especially the visual display, seems to alienate the majority of older drivers’*.

Other factors to note in respect of technology in vehicles and older people are that actual use may change perceptions, and acceptance levels. For example, in a study by Bryden *et al.*, (2014), 20 participants in Australia aged 65+ trialed a navigation system in their own vehicle over a period of four to six weeks. Pre-use and post-use surveys were completed, and analysis showed that after the trial participants were more likely to express positive attitudes and express an interest in using navigation systems. Trial of the navigation system was seen to be useful to help clarify older drivers' attitudes towards navigation systems, and that they had fewer concerns about some use and performance issues after the trial.

2.4.2 Learning how to use technologies

In The Hartford Center for Mature Market Excellence and MIT AgeLab (2014) study of older drivers in the US, participants were asked how they learned how to use in-vehicle technologies. Of those who already owned a vehicle with one or more of the technologies, most used their Owner's Manual (47%) to learn how to use them, followed by trial and error (26%) and their car dealer (20%).

Research suggested that older drivers learn how to use new technology differently compared to younger drivers. Abraham *et al.*, (2016) asked participants how they learned to use the technology in their vehicles and found that older adults prefer to use the vehicle manual or have the car dealer explain it to them, whereas younger adults prefer to use trial-and-error or have a friend or family member explain the technology. Both younger and middle-aged adults welcomed the option of having the car teach them how to use the technology, but older adults were significantly less interested in the idea. The survey further suggested that training and perceived ease-of-use of in-vehicle technology directly correlate with eventual adoption of the technology.

In a US survey by Llaneras (2006), exploring adaptive cruise control (ACC) use, older drivers aged 60+ were most likely to read the entire ACC section in the owner's manual, compared to younger drivers. Similar differences were observed among other technologies. When it comes to learning how to use it, ease-of-use and difficulty using ACC were similar across all age groups, suggesting that older drivers do not find this type of technology more or less difficult to use than younger or middle-aged drivers.

2.4.3 Mobility scooters

Thoreau (2015) carried out a literature review to understand the usage and impact of mobility scooters, and the importance they play among those who use them. Overall, the review found that the literature on mobility scooters is sparse, however two studies are relevant to this review.

Barton *et al.*, (2014) surveyed 480 mobility scooter users of all ages in the UK, which was the first large-scale survey of mobility scooter users in the UK. Respondents stated that they chose to use a mobility scooter as opposed to wheelchair as it is easier to use (61%) and more comfortable (52%). Almost three quarters (74%) said they would not make the same trips they do without the use of their scooter, highlighting the reliance on scooters for mobility. Although 47% of respondents to the survey were aged 65+, this study did not analyse results according to age groups. The only identified study that has focussed specifically on older people and mobility scooters is May *et al.*, (2010) that carried out a survey and focus groups with scooter users over the age of 65. Participants first started using their scooters to maintain mobility, as a result of losing physical capabilities or stopping driving. The

use of a scooter enhanced their mobility, allowing them travel to more destinations, achieve more daily tasks, maintain more independence, and increase their sense of wellbeing. The authors conclude that mobility scooters are generally viewed positively by older people, they provide older people with increased mobility and freedom to move independently outside the house, and in some cases may prevent older people from being housebound (May *et al.*, 2010).

2.4.4 Electric bicycles

Similar to mobility scooters, research suggests that electric bicycles may be able to provide increased mobility for older people.

A study by MacArthur *et al.*, (2014) surveyed 533 electric bike users across North America. The study showed that the demographics of electric bike users differs from that of regular bike users, and includes populations that tend to use regular bikes less, including older adults and, people with physical limitations. Respondents were asked about the main reasons for buying or converting to using an electric bike, with results highlighting notable differences between older (55+) and younger (under 55) adults. Older respondents were less likely to buy or convert to an electric bike in order to replace car trips (61% of older respondents compared to 72% of younger adults), but were more likely to do so for health reasons, either to increase physical fitness or because their medical condition reduced their ability to ride a standard bike. When asked about the main reason for using their electric bike, older respondents said they were more likely to use it for recreation (31% of older adults compared to 9% of younger adults). They were also more likely to use it for 'local trips (shopping and errands)', although this difference was not statistically significant.

Johnson and Rose (2015) carried out a similar survey of 529 electric bike owners in Australia, although they focussed only on older people, who were aged 65 to 88 years. Most had been regular cyclists prior to purchasing an electric bike. The main reasons for purchasing an electric bike were to be able to ride with less effort (53.6%), to replace car trips (50.7%), maintain or increase health and fitness (42.0%), ride on hills (40.6%), and to ride with a medical condition (34.8%). Among those who were previously regular cyclists, reasons for changing to an electric bike often included lifestyle changes related to retirement (such as moving to a hilly area) which meant pedal bikes were no longer suitable or practical. Supporting this, 11.6% changed to an electric bike because of their age and 16.3% did so because of a physical limitation. The main use of electric bikes was to make local trips (69.6%), followed by visiting friends (31.9%). The study found that many people shifted from using a car to using an electric bike for their trips, suggesting that electric bikes provide a fun and practical option for older people to travel. However, the study suggests that electric bikes could improve mobility among older people as a lot of the respondents stated that they are able to make more frequent trips when using their electric bike compared to when they would walk or cycle.

2.4.5 Conclusions

This section outlined the research, although limited, on older people making use of in-vehicle technologies and technologies that provide motorised mobility. From the systematic review by Eby *et al.*, (2015) it appears that older people are making use of a variety of in-vehicle technologies, have high satisfaction from them, and benefit from them. Again, though, limitations arise regarding the

definition of 'older' people. This section also shows that older people's method of learning new technologies differ with that of younger adults.

This section of the review has also used the examples of mobility scooters and electric bicycles to highlight the potential benefits of providing motorised mobility to older people through means other than private vehicles, and reasons for using these technologies (research actively engaging older people in CAV research is covered in the subsequent section).

It is important to note the fact that older people are willing to engage with technology in vehicles, and to adopt other means of personal transport where that provides additional mobility. Deployment of CAV solutions to this demographic will though need to be mindful of the fact that the way that they 'learn', and access information may not necessarily be the same as for younger age groups. Failure to adequately consider this could mean that CAV use by older people may not deliver as many benefits as it has the potential to do.

2.5 Experience of older people being exposed to, or trialling connected and/or autonomous vehicles

To date there have been few opportunities for research that has specifically explored CAV with older people, particularly in respect of any form of trials of such vehicles. Older people have been included in other research activity related to CAV though, such as representative surveys of motorists exploring the issues related to the introduction of, and use of CAV (for example see section 2.3 above). There are also limited examples of studies that have considered AV and CAV with user(s) or user groups through more qualitative methods.

In respect of physical trials and experiments related to CAV, older people have been involved in research looking at the deployment of a range of assistive technologies and advanced driver assistance technologies that are being developed and deployed in some vehicles at present, and which will contribute to a wider set of technologies in vehicles that in the future will have the capability to operate in a fully autonomous mode (level 5 as discussed in the 'Levels of Autonomy' note on page iii). Activity in these areas provides a degree of 'proxy' at present for the lack of engagement in CAV trials or research – although the caveat has to be applied that such technologies fall short of the true autonomous vehicles that will eventually be seen on the streets.

2.5.1 Vehicle technology trials / studies involving older people

The US National Highway Traffic Safety Administration commissioned a series of studies to look at how a range of vehicle automation technologies had been received by both *younger* (under 65) and *older* drivers (over 65). These studies engaged with over five thousand participants in the US, and considered the following technologies: reversing aids (proximity sensing systems, rear-view video cameras), adaptive cruise control (ACC)⁴, advanced headlamps, and built-in vehicle navigation systems. Of these technologies, adaptive cruise control (ACC) is perhaps the one that provides the greatest level of automation, and along with parking assist systems the closest experience to AV in current driver aids.

Adaptive Cruise Control (ACC)

In a report for the US National Highway Traffic Safety Administration looked at how ACC had been received by a range of older and younger drivers (Jenness *et al.*, 2008b). Through the initial survey (and follow up interviews) conducted with owners of ACC systems the intention was to provide insights into drivers' understanding of the functional capabilities of different manufacturers systems and what (if any) impact it had on their driving behaviour. There were few items on which the responses from older and younger respondents differed significantly with respect to their experiences, the exceptions being:

- Older participants (73.7%) were more likely than younger participants (63.6%) to have used the vehicle manual to learn how to use ACC. (This was the only statistically significant difference between the two age groups)

⁴ Adaptive cruise control (ACC) is designed to maintain a set speed and, when applicable, adjust the set speed to maintain a specified distance from a lead vehicle. It will automatically slow down or speed up in responses to changes in the lead vehicle's speed. At present, it is more likely found on expensive luxury cars although the technology is starting to spread through vehicle ranges.

- Older drivers preferred larger gaps (between them and the vehicle they were following) and younger driver's smaller gaps.
- The younger respondents were more likely to have safety concerns about ACC and were more likely to report a need for system improvements.

Although not broken down by age group, only thirty-eight percent of ACC owners thought that using ACC made them a safer driver than using only conventional cruise control and 7 percent thought that it made them less safe. A majority (54%) thought that using ACC made them neither more nor less safe. Both age groups highlighted issues in relation to 'understanding' how to use the technology, and what such systems are capable of. This included a lack of awareness of the limitations of the system and an overestimation of the effectiveness of ACC in helping to avoid collisions – most drivers were unaware that the technology would not 'see' a stationary vehicle in their lane.

In a further review of driver assistance technologies (Eby *et al.*, 2015) adaptive cruise control (ACC) is again the aid that provides the greatest level of automation. The authors identified a number of studies that investigated the use and perception of ACC among older adults. In the studies identified, 31–50% of participants were 'older drivers'. The review found that older drivers value ACC and use it frequently, more so than younger drivers do. Older drivers use ACC frequently on freeways, and set it at the maximum distance possible between them and the vehicle in front (where this is an option), and follow vehicles less closely when using ACC. Research with older drivers suggests that many believe using an ACC system makes them a better driver and that this technology would help avoid collisions if a vehicle ahead were to stop. However, studies also suggest that ACC use among older drivers can result in reduced situational awareness, late braking for critical events, and overconfidence in the system. It was proposed that this might be due to older drivers not fully understanding the remit of ACC and the situations under which it operates, although this is true for drivers of other ages. The authors conclude that ACC is suitable for older drivers, but that *"these systems should come with proper training not only on the operation of the systems but also on the situations for which the ACC systems are not designed to operate"*.

Hand-over of control

In a recent study (Körber *et al.*, 2016), a vehicle simulator was used to investigate how older drivers (classified here as aged 60 - 79) might compare to younger drivers (aged 28 or less) in a critical traffic event requiring take-over of control in a highly automated vehicle. The conditions of the take-over situation were manipulated by adding a verbal non-driving task (20 questions) and by varying traffic density. The findings show that older participants were able to take over as fast and as well as the younger participants and do not have a disproportional decrease in performance or quality with the additional task or high situational complexity. Both age groups were able to adapt to the experience of take-over situations in the same way, independently of traffic density: However, older drivers generally braked more often and more strongly and maintained a higher time to collision (TTC) in the take-over situations.

The authors note that it is difficult to generalize these specific results to older drivers in general since a selection bias might exist in the study in that only cognitively very fit older participants might have taken part. Cognitive decline is seen to be highly variable in its degree, influenced by factors such as

personal lifestyle, experiences, and genetics. Older drivers at the lower end of the scale of possible functioning may have solved this situation less successfully, despite being of a similar age. To avoid any risk of collision and injury the study was conducted in a static driving simulator which meant it was not possible for the participants to feel acceleration and braking and it is imaginable that, because of the lack of consequences, a difference in risky behaviour in comparison to a naturalistic drive might exist.

Parking assist technology⁵

There are advanced driver assistance systems being introduced now that are intended to promote wellbeing by reducing the amount of stress associated with particular tasks and manoeuvres. This report (Reimer *et al.*, 2010) covers the initial findings of two experiments undertaken to evaluate drivers' reactions to two such systems. The first is a semiautonomous system for assisted parallel parking and the second is a cross traffic alert system designed to warn drivers of encroaching vehicles when they are attempting to back out of parking spaces. Participants in the study included a gender-based group aged 60-69 who were compared with two younger groups.

In neither set of experiments were there any statistically significant age-related results. The results for the parking assist experiment were in accordance with the study hypothesis that use of the semi-automated parallel parking assistance system would result in reduced stress levels in the participants (measured through objective physiological data and self-reported stress levels). As noted, the results were consistent across age groups and across gender in the study sample. For the second test, the reversing alert system, the most significant finding was the observation that drivers were more likely to appropriately stop and yield to an approaching vehicle during trials when the cross traffic alert system was active. This appears meaningful in that it suggests possibility that a reduction in accidents when backing up the vehicle could be the effective result. Again, as already noted age was not a relevant factor in the results.

2.5.2 Other research activity in relation to older people and CAV

The growing interest in the potential role for CAV in meeting mobility needs for older people has led to a degree of interest in this topic from academics, policy makers and industry, leading for example to the current UK government sponsorship for the FLOURISH project. In the US, The Florida Department of Transportation (FDOT) commissioned Florida State University to research whether (and how) automated and connected vehicle technology could enhance the mobility of ageing populations (Duncan, *et al.*, 2015). Although this study did not involve any trials, researchers did attempt to survey five thousand Florida households - with around five hundred responses (approx. 10% response rate). Older people were deliberately over-sampled in the process so that around half of respondents were aged 65 or older. Some relevant findings from the study included:

- Around 85% of respondents aged up to 50 claimed success in using new technologies, whilst this fell to just over 60% for the 50-64 group, and 50% for those older.
- Those 65+ often see less benefit, in areas such as 'mobility for non-drivers' from AV than those in younger groups.

⁵ A semi-autonomous system for parallel parking that detects appropriately sized parking spaces and actively steers the vehicle into the parking space while the driver controls the accelerator and brake.

- Those 65+ have greater concerns, for example it being ‘hard to learn how to use an AV’ than those in younger groups.

2.5.3 Conclusions

Although there have only been limited research studies to date that have actively engaged older people in CAV research, there are still relevant lessons emerging from a range of sources related to some of the facilitating technologies likely to lead to the development of CAV. What are notable though are the limited differences between older and younger drivers in most of the research reported above. It is perhaps worth noting the caveat in the Körber *et al.*, study (2016), about the cognitive (and perhaps physical) state of participants, and whether these same results might be seen across a wider spectrum of older people – in particular those that may have ceased driving.

There are also indications that delivery of technologies in CAV and the ways in which people learn about their use (and capabilities) may be different depending on age, and that this could be an important factor in terms of take-up of some of these technologies now and when they come together to create truly autonomous vehicles in the future.

2.6 The user needs and expectations of those with some form of physical or cognitive impairment

One of the key issues being considered by the Flourish project is how those with some form of mild cognitive impairment (MCI) may benefit from the wider availability of CAV. To help put this into context, this section of the user needs review considers how both physical and cognitive health issues might impact on the mobility needs and aspirations in particular of older people. It is expected that some of these needs and expectations will also be relevant to those in the wider population who may be experiencing similar conditions, but the review has not explicitly explored these issues with that wider demographic.

2.6.1 Mild Cognitive Impairment (MCI)

Self-regulation and driving cessation

The impact of MCI on older people will to an extent depend on the severity of the condition. Evidence indicates that older drivers modify their driving to compensate for perceived changes in sensory and cognitive abilities or physical functioning, and for some this also leads to driving cessation. Devlin *et al.*, (2016) studied self-regulation in relation to cognitive impairments with a group of Australian older drivers. The study authors suggest this provides evidence that self-regulation of peak-hour journeys, journeys at night and in poor weather conditions was more common amongst those with cognitive impairment. Interestingly, this study also noted that there was perhaps a decreased awareness of these self-regulatory behaviours amongst the drivers with MCI, suggesting to the authors that some other factors may also be playing a part in this behaviour change.

Another recent study (Rapoport *et al.*, 2016), explored the role of cognitive issues with older drivers in Canada, and found some associations between cognitive change and changes in self-reported driving frequency and avoidance behaviours. The study followed a group of nearly a thousand older people over two years, and found that cognitive slowing (and what was termed ‘increased executive dysfunction’) appeared to have a ‘modest association’ with declines in perceived driving abilities and led to greater avoidance of driving in challenging situations over time. The authors note that two years is likely insufficient time to capture more significant change, particularly in a sample that in their terms remained ‘highly cognitively intact’ over the study period.

Self-regulation was reviewed in an earlier US study focussed on participants aged 70 and over (Freund & Szinovacz, 2002). Although results in this work suggested that the distances driven by older people with cognitive impairment had declined (see Table 8 below), the study also highlighted concerns over the degree of awareness amongst the older drivers of driving problems arising from their condition. It was not clear from the study at what level of cognitive impairment that older people might begin to change their driving behaviours. Even with some degree of cognitive impairment some individuals continued to drive, perhaps to maintain their independence. The role of partners or other drivers in the household was also seen to moderate the effect of cognitive issues on driving restriction and cessation.

Table 8 Effect of Cognition on Driving Involvement, by Gender

Driving Involvement	Severely	Mildly	Not
---------------------	----------	--------	-----

The mobility of older people, and the future role of Connected Autonomous Vehicles

	Impaired	Impaired	Impaired
Men			
Does not drive	42.80	19.40	8.32
Drives short distances	37.40	49.70	25.36
Drives long distances	19.80	30.90	66.32
No of participants	74	124	2,089
Women			
Does not drive	75.60	64.20	21.60
Drives short distances	18.30	28.10	42.40
Drives long distances	6.10	7.70	36.00
No of participants	118	202	3,052

Source: Freund, B. & Szinovacz, M. 2002. Effects of Cognition on Driving Involvement Among the Oldest Old: Variations by Gender and Alternative Transportation Opportunities.

Note: Data are in percentages, unless otherwise noted.

This study also highlighted another key issue in respect of the role of gender in responses to cognitive impairment. Both driving restriction and cessation were more common amongst female participants (with the sample intended to be representative of the US population), and the association seen between cognition and driving involvement was also seen to differ between men and women. In the case of the male participants, those with low cognitive functioning would tend to restrict their driving to short distances, whereas for women with similarly low cognitive functioning the tendency was to cease driving. Gender-related differences were also seen in respect of the role of other drivers in the household, with for example driving cessation more likely for women with low cognitive function when there was another driver in the household.

Motivations for self-regulation of driving behaviours by older people (aged 75 and over) was studied in Melbourne Australia (Molnar et al., 2013). The key findings from this study were that driving avoidance is often more closely related to lifestyle or individual preferences than to self-regulation, and where the latter does occur it may be tied to the context of the specific situation in which it is being examined. The study reports fewer respondents citing difficulties in visual, cognitive, or psychomotor skills in relation to driving, as opposed to more general feelings of discomfort or lack of safety (which potentially could be seen to be related in part to cognition) although there were still some explicit examples of cognitive issues. For example, what was termed a sizable minority had cited a difficulty in concentrating on more than one thing at a time as a reason to avoid driving in an unfamiliar area. The study again highlighted gender differences, with the authors finding that men reported less self-regulation than women for several driving situations (e.g. driving at night, in bad weather, in unfamiliar areas, and on the freeway).

In perhaps clearer results (Kowalski et al., 2012), it was seen that those older people who reported cognitive impairment on multiple measures were more likely to have given up driving. This Canadian study also made the observation that those with MCI across multiple measures were also perhaps more aware of the limitations in respect of their driving ability, and thus were more likely to consider driving cessation in response. The authors did caution though that their participants were self-selected and 'fairly cognitively intact', thus some caution should be given to generalizing this to the wider population of older people.

Predicting / predictors of change

The presence of MCI can also be a predictor of changes in driving ability and behaviour for older people. In a study that followed individuals over a five-year period (O'Connor *et al.*, 2010), older people with cognitive deficits started with poorer baseline mobility, and then showed significantly greater declines in driving frequency, and greater increases in driving difficulty, over the 5 years than participants without the condition. Aspects of driving considered included: life space (the spatial extent of a person's mobility), driving space, driving frequency (average number of driving days per week), and driving difficulty. Study participants were aged 65 and older, and three quarters were women, although MCI was more prevalent in the men taking part. The authors conclude that MCI status is a predictor of declines in driving frequency and increases in driving difficulty, and that this finding is consistent with other work in this area, although the participants were highly educated and Caucasian – so may not be fully reflective of the wider population.

'Cognitive competence' was also seen as a stronger predictor of driving cessation than physical health issues in drivers aged 70 and over in an Australian study (Anstey *et al.*, 2006). Using data from a cohort followed from 1992-1998, the most reliable health-related baseline predictor of driving cessation was self-rated health, a measure that captured aspects of physical and psychological health. Researchers also found that an older person's performance on a range of cognitive measures would predict subsequent driving cessation. So for example, poor symbol recall was the strongest predictor of driving cessation at 1 year, and poor processing speed, immediate recall, symbol recall, and self-rated health were the strongest predictors of driving cessation at 2 years. The study also found that 'poorer verbal reasoning' could be seen to be associated with driving cessation, implying a role for higher-order cognitive function on a decision to cease driving. The findings of this study highlight the importance of cognitive decline short of dementia as being a key indicator of driving cessation. The study has also highlighted that sensory function and physical health may be less significant than psychological function in predicting driving cessation.

Dementia

Although not a group of people being considered specifically in the Flourish project, there may be an overlap in some of the issues relating to those with MCI and early stages of dementia. As a consequence, it is worth briefly considering the impact of dementia on the ability of older people to drive. As noted earlier, dementia involves more significant changes to cognitive functions than MCI, and over time these impairments will affect areas such as memory, attention, judgement and motor coordination, meaning drivers with dementia can experience problems with navigation, signal interpretation, problem solving, decision making, recognition, and awareness (Bradshaw *et al.*, 2013). Thus older people experiencing such difficulties will find it challenging to drive in complex situations and as a result, could pose a significant risk to themselves and others on the road. Reviewing these issues in a report for the Royal Automobile Club of Victoria (RACV) it was noted that drivers experiencing dementia will initially need to curtail their driving and eventually to cease driving altogether, with consequences for independence, access to services and opportunities to participate in community and social activities (ibid).

The older–old (those aged 85 years or more) are more at risk of dementia, with an estimate for Australia for example proposing rates as high as one in four older people (Access Economics, 2005 in Bradshaw *et al.*, 2013). For those older drivers who do develop dementia there will be a progression of driving difficulties. These may begin with forgetting the purpose of a trip or where the car was parked for example, before progressing to more significant problems such as spatial disorientation on familiar routes, poor judgement, gaps in attention and difficulty handling multiple stimuli. These cognitive (and perceptual abilities) have been identified as more significant than many physical defects (such as hand strength or musculo-skeletal function) as a predictor of crash risk and driving performance in older drivers (Anstey *et al.*, 2005). The RACV review (Bradshaw *et al.*, 2013) concludes that there are no ‘vehicle aids’ that are regarded as helpful for dementia sufferers per se, and a strong view that systems such as Satnav could even have a negative impact because of the potential they might have to cause confusion.

2.6.2 Physical impairment

The normal physical processes of aging will in most instances lead to an inevitable physiological decline in older age. Some of the features of this decline, and the potential problems that might result in respect of driving are captured in Table 10 below.

Table 9 Age-related impairments, driving problems and in-vehicle interventions or equipment assistance. (Modified from Young et al., 2016 (In press))

Age-related Impairments (physical)	Driving Problems
Reduced vision, including reductions in visual acuity, contrast sensitivity, visual field, dark adaptation and glare recovery	Difficulty seeing other road users (particularly at night); Difficulty reading road and traffic signs
Musculoskeletal declines and strength loss	Difficulty turning head/neck, Reduced peripheral vision; Failure to notice obstacles while manoeuvring/reversing; Lane excursion; Difficulty merging and lane changes Difficulty in getting in and out of vehicles Difficulty in gripping steering wheel, or in using other controls in vehicle
Increased frailty	Reduced tolerance to injury in the event of a crash
Increased susceptibility to fatigue	Concerns over increased susceptibility to become fatigued on long journeys
General effects of aging	Concerns over inability to cope with a breakdown, driving to unfamiliar places, at night, or in congested areas

The physiological issues listed above can all have impacts on a person’s ability to drive a vehicle, and could contribute to driving cessation. For reasons of time and space this review has not considered a detailed literature in respect of all of the potential physiological issues that might impact on out-of-home mobility, and the ability to use a car. Some of these factors and consequences are though considered in respect of a common complaint of older age, arthritis.

It is noted by Bradshaw *et al.*, (2013) that developing a chronic disease can also restrict an older person's ability to drive, and arthritis seems in particular to have such an impact. It can cause a range of problems, including pain, fatigue, reduced movement, and a loss of muscular strength and reaction time, all of which could impact on the ability to drive (safely). It is a condition which increases in prevalence with older age, and with ageing populations around the world it is expected that there will be an exponential growth in the number of drivers with arthritis on the road in the future. The issues were explored by a Canadian study (Vrkljan *et al.*, 2010), using focus groups. Although the study identified constraints consistent with other studies (e.g. reversing), it also highlighted impacts on simple driving manoeuvres such as turning a corner, and a range of problems were identified in respect of simple functions in the vehicle (turning a key, reaching for a seatbelt for example) and outside it (filling up with petrol or putting air in the tyres), and it was noted that many cars that had adaptations to make some of these things easier tended to be high-end and expensive. Participants in this small study (n=11) were also using self-regulation to compensate for their condition in order to keep driving, such as avoiding certain routes. They might also modify their driving routine planning alternate routes, incorporating rest breaks when traveling longer distances and (legitimately) using parking facilities for disabled drivers.

Mobility and other physical impairments may also influence the vehicles that older people choose to own. This latter issue was considered explicitly in a more recent study (Vrkljan *et al.*, 2016), where functional performance, (as measured by a clinical assessment of strength, balance, and joint mobility) was related to the type of vehicle driven for a sample of over 900 older citizens across Canada. Participants were aged 70 or over, and were still driving at least four times a week. The findings indicate that functional performance (strength, coordination, and balance) did not influence the type of vehicle driven, although the results do indicate that there is an age and gender effect on vehicle choice, larger vehicles are more likely to be driven by older male drivers and those of larger stature and girth, whilst smaller vehicles are more likely to be driven by women and by those of smaller stature and girth. In respect of some specific conditions, older drivers who reported balance problems, or who had either osteoporosis or osteo/rheumatoid arthritis, were more likely to have smaller cars. It was noted that in Canada these conditions tend to affect a higher number of older women than older men.

2.6.3 How might the deployment of CAV impact on these issues?

Some consideration has already been given as to how CAV might have a role to play in responding to the cognitive and physical impairment issues described above in a paper that estimates the travel impact of providing mobility to the non-driving population, and older people restricted in their travel by medical conditions (Harper *et al.*, 2015). Based on US statistics from 2009, the study estimates that providing transport to these groups to remedy shortfalls compared to the rest of the population would lead to an overall increase in vehicle miles travelled (VMT) of 12% in the US. Whilst this would increase mobility and accessibility for older people, non-drivers and those with medical conditions, it would also reflect a significant increase in traffic – underscoring that the move to CAV has the potential to generate problems as well as solutions.

2.6.4 Conclusions

There does appear to be evidence that those experiencing MCI are more likely to be self regulating their driving, although other factors such as another driver in the household might reduce the impacts of this. There are also indications that there may be a gender effect at play, with older women with MCI more likely to cease driving than men. MCI does also appear to be a reasonable predictor of driving problems, reductions in driving and eventually driving cessation. In a more serious form, dementia, then older drivers are seen to be more dangerous, and the condition can also be a predictor of higher accident rates.

Physical impairment can also impact on older people and out-of-home mobility, and the example of arthritis is explored here. It is seen to impact on drivers both in and out of the car, although driver aids and assistance technologies may provide some support. Such impairment can also impact on the amount, and types of journeys being made, and even on the types of vehicle that older people might drive – which may have financial consequences. Whilst it is possible to compensate for physical impairments in some cases, there are no aids to help those with serious cognitive issues – such as dementia. The future potential of CAV to facilitate full mobility for such people could result in a significant increase in vehicle miles travelled, and whilst addressing a social sustainability issue may then impact on an environmental issue.

2.7 Opinions about future mobility for those approaching older age

This section of the review looks to understand what aspirations those approaching older age (in their 40's, 50's and 60's) might have for their mobility when they are aged 70 or older. Some indications of this can be seen in the wider surveys of the general population in respect of the future of CAV (See Section 2.3 for some material from such surveys). It is also reflected in a specific series of academic studies in the last decade or so looking to explore the impacts of those described as the 'baby-boomer' generation, born during the two decades following the Second World War, the oldest of whom are now 70, and the youngest 50.

2.7.1 'Baby boomers' and mobility in later life

Two Scandinavian studies have looked specifically at the mobility aspirations for the baby boomers. The first focussed on a group in Sweden aged 56-57 who detailed their current driving behaviours before considering if things might be different when they were aged 80 (Hakamies-Blomqvist *et al.*, 2005). Around half of the study group stated that they had already modified their driving behaviours in the last 10-15 years (although more likely amongst female drivers than male), to avoid driving in bad weather or long distances for example. It was also noted that the women drivers with high annual mileage also had more issues with using public transport than similar men.

In respect of their mobility at 80, there was an expectation of being able to drive far into old age. Those that did expect to continue to drive saw it as important for themselves to be able to provide lifts for those less able. The study did though highlight a gender issue, with one third of the women believing they would not be driving at this age (compared to only 14% of men). In part this might relate to the fact that this cohort still sees men as the dominant 'drivers' in households, and the subsequent lack of experience and skills built up over time by women leaves them less able to cope with age-related impairments or disabilities.

The status of a group of Danish baby boomers when they were studied recently was that they were healthy, independent and highly mobile, and they had good levels of access to a car. They expressed an optimistic outlook on their level of mobility, their capability to use various travel modes and to lead an independent life in the future (Siren, & Haustein, 2013). However, the study also found a gender difference, with women having significantly lower annual mileage, driving less often and more frequently using a range of different modes of transportation. Differences also emerged in respect of being 'chauffered'. The women tended to chauffeur a wider range of other people, while men predominately drive their spouses, and the women reported being chauffeured around more frequently, and being dependent on others for their transport. As in the Swedish study above, the female participants thought it was less likely that they would be driving when they were aged 80. Participants scored the likelihood of this outcome on a scale of 1-6, where 1 was very likely and 6 not at all likely, with the male mean score being 3.25 and the female 4.01. The study concludes that baby boomers will have a high demand for mobility in later life (both from the transport system and their own personal mobility), but this group will not be heterogeneous, and appear to exhibit a range of potential to meet their future mobility needs. This factor, and the differences between women and men (which continue to reflect those observed in current older cohorts), suggest that scenarios about

a coming generation of older people whose need for external support in old age will be minimal is seen by these authors as 'unrealistic'.

In a New Zealand study exploring baby boomers' anticipation of retirement (Winston & Barnes, 2007), transport and mobility did not appear to be a strong concern. The participants, mainly academic women in their 40's and 50's did though expect to maintain a range of activities which might imply future mobility needs. These ranged from continuing to work (with a wide range of expected retirement ages – or none at all) through to volunteering and social activities such as spending time with family and friends. There were concerns noted though about continuing (good) health and sufficient financial resources to facilitate these expectations.

Using a scenario-based approach, a Dutch study looked forward twelve years to explore the travel patterns of older people in 2020 (Arentze *et al.*, 2008). One feature of the study was to compare the activity-travel behaviour of older people now against that of 2020. Building on existing trends in the Netherlands the study suggests that the elderly in the future would need to work to an older age, would look to avoid travel in the morning peak, and consider more diversity of location in retirement. The net result of such changes would be a significant increase in travel demands as well as temporal, spatial and modal shifts in mobility patterns. A further finding was that older baby boomers (those in their 50s) had fewer concerns about retirement than those in their 40s.

The future transportation needs of a small group of baby boomers from low-density suburbs in the US was the focus of a recent US study (Pape & Agrawal, 2014). The fifteen participants were interviewed about both these needs and the impacts they might have on retirement location. There was an expectation of continued driving into older age by most participants, and although all of the interviewees anticipated giving up driving they had made no plans for it. This was not seen as an issue that would affect them for some time. Alternate transport options were not considered by most people in respect of their retirement location plans, although following driving cessation there was an expectation that they would move to a central location with services and amenities and well served by public transport. Interestingly, walking was not seen as a mode of transportation, more a leisure activity, even for those who contemplated retiring to a more walkable neighbourhood.

When a group of adults aged 62–85 (number of participants=38) living in San Francisco or Oakland California were asked to think about a time when they might not be able to drive or get around on their own, most of them had not given serious consideration as to what they would do under those circumstances (Yen *et al.*, 2012). This was notwithstanding the fact that many of the participants travelled to non-neighbourhood locations to undertake a variety of activities, suggesting that it was common to live on a geographic scale greater than their own residential neighbourhood and that meeting their social and material needs required them to access a broader space.

A rural perspective on out-of-home mobility issues was considered in a small US study looking at the retirement needs and preparation of those aged 45 – 64 in rural North Carolina (Glass & Flynn, 2000). Although respondents stated that their future (post-retirement) well-being was important to them, and that they would need to learn to adjust to the ageing process (including physical changes), few

were taking action on these issues. They considered public transport to be unimportant and had taken very few actions in preparation for their future mobility needs - instead finances and health issues were the top concerns. The authors hypothesised that transport may not be an issue because the expectation was of continuing to drive, or that actually there was no public transport in that rural area to consider anyway. Whilst the circumstances of the rural US are somewhat different in scale to countries such as the UK, the increasing paucity of transport alternatives to a car in the UK, and the very high levels of car ownership in rural populations here does suggest some relevance for this study.

2.7.2 Consideration of relevant policy perspectives

Exploring the future mobility of baby boomers from the transportation planner's perspective (Coughlin, 2009), highlights both a shortfall in alternatives to the car, and the likelihood that services that are deployed might fail to meet the requirements of the coming cohort of older people. For example, this group are likely to want (good) design, comfort, and ways of managing their use of any transport alternatives online, 24/7. Four factors identified as likely to have influence on the travel behaviour of the baby boomer cohort are: the behaviours in particular of older boomer women, expansion of caregiving, working longer, and leisure activity in the future. Exploring these issues with metropolitan transport planning bodies in the US the expectation was that current investment strategies would leave baby boomers 'auto dependant', either as drivers, or else reliant on lifts. There would be a need for major transport investment to provide alternatives if baby boomers choose to age-in-place, reflecting their current location outside the centre of major metropolitan areas. The study also notes that the expectation that new information technology and technology systems might help prolong driving for this cohort run the risk that the 'new mental models' required to use such aids may conflict with drivers who have spent 40 or 50 years not using such assistance, and may struggle to adapt.

Stakeholders involved with older driver's transport and mobility (including law enforcement, licensing, planning, policy, and programming) who engaged in an exercise exploring 'safe mobility' for baby boomers in older age in S. Africa focused on a range of economic consequences (Classen *et al.*, 2011). With an expectation that there would be both a reduction in driving, and driving cessation they foresee reduced spending as a consequence of less access to goods and services. This reduced spending also potentially impacting on quality of life. Conversely there are seen to be economic benefits to providing alternate transport options, at an individual and societal level.

2.7.3 Conclusions

Research has been undertaken with the coming cohort of older people, the (later) baby boomer generation in their late 50s and early 60s now. This group expect to continue be mobile, and to be consumers of mobility in later life (when talking to them about their 80s). There is a general expectation of continuing to drive, although even within this highly auto-mobile generation the women are more likely than men to be thinking that they might have stopped driving by that age. Across men and women, and across different countries, there seems to be little planning for this eventuality though – consistent with current older people cohorts.

Transport and mobility are not necessarily seen as important issues for the retirement years, and are not necessarily being factored into location decisions, even though these coming older people are likely to be engaging activities outside of their immediate neighbourhood. It is not just the baby boomers who are not necessarily planning either, there is some evidence that transport planners are not particularly responding to the impending issue of a growing older population with restricted mobility either. This could have both social and economic consequences.

Making people aware of the options provided by CAV before they reach a point of not driving might help them adjust to the idea of using them, and to understand how they might provide alternate means of delivering the mobility they need to maintain existing lifestyles. As seen in current cohorts of older people giving up driving, exposing people to, and letting them experience alternate modes can help the transition away from driving (Musselwhite & Shergold, 2013). Using such an approach may both smooth and encourage a move away from driving to driverless vehicles, and better engage older people in understanding the potential benefits such a move might bring.

3 Conclusions

Out of home mobility is seen to be a vital element in older people's lives, helping to maintain their quality of life, their wellbeing and health. It is a key enabler of social connectedness and social activity. It also facilitates involvement in activities such as volunteering, another key enabler of community cohesion. The process of ageing will though inevitably present physical or cognitive issues for many, and reductions in mobility in respect of journeys and distance travelled will be experienced by most people as they age. This at a time when a growing older population means that the number and proportion of such people in most (if not all) developed nations will increase significantly over coming decades. The resultant transport disadvantage may not be evenly felt, with evidence suggesting that the older old, women and those in rural communities are likely to experience more problems. Alternatives are not always easily found, and for those who can no longer use a car then a range of negative health outcomes are unfortunately more commonplace.

Whilst older people do seem to be willing to embrace a range of technological aids and assistance in vehicles (particularly related to safety), there is seemingly less appetite for CAV as a response. This finding is though often based on polling amongst those who are not yet aged 70. Younger people seem more open to the potential, yet it will be two or three decades before they may actually get to experience widespread availability of the technology themselves as older people, and opinions may change over that time. As already noted, older people use of a variety of in-vehicle technologies, gaining high satisfaction and benefit from them. Differences emerge though in how they are used, and how they are 'learnt' and that this could be an important factor in terms of take-up of some of these technologies now and also when they come together to create truly autonomous vehicles in the future. Other current mobility options facilitating out-of-home activity, such as mobility scooters and electric bicycles, are seen to be beneficial.

There is limited research involving older people and CAV, and thus it is necessary to look at some of the expected facilitating technologies to gain potential insights. Most notably, there are limited differences between older and younger drivers in most of the research reviewed, although this has not necessarily considered those with physical and cognitive impairment, nor considered those who have ceased to drive as a consequence. Those experiencing MCI are more likely to self regulate their driving, although actual driving cessation is more likely for women than men with the condition. It also appears to be a reasonable predictor of driving problems, reductions in driving and eventually driving cessation. Its more serious form, dementia, can make drivers more dangerous, and be an indicator for higher accident rates. A range of physical impairment can also impact on older people and although driver aids and assistance technologies may provide some support, such impairment can impact on how often, where and when journeys are made. It may even influence the choice of vehicle owned and driven. Whilst it is possible to compensate for some physical impairments, there are no aids to help those with serious cognitive issues – such as dementia.

Looking to the next generation of those about to reach their 70s and 80s, these people expect to continue be mobile, and to be consumers of mobility in later life. In the main, they believe they will

continue to drive, although women are more likely than men to be thinking that they might have stopped driving by the time they reach the age of 80. There is little evidence that they are planning for this eventuality though, irrespective of location or country – a situation somewhat consistent with current cohorts of older people. For those approaching retirement, transport and mobility are not seen as important issues, and are not necessarily elements of location decisions, even though these coming older people are likely to be engaging activities outside of their immediate neighbourhood. Looking at some of these issues from a wider perspective, it is not just the next cohort of those who will be in their 70s who are giving limited thought to their future mobility needs, there is also seen to be a shortfall by those planning the transport networks of the future to the impending issue of a growing older population with restricted mobility. This could have both social and economic consequences. The future potential of CAV to help alleviate some of these problems will not be without its own issues though, and facilitating full mobility for those whose mobility is impaired could lead to a significant increase in vehicle miles travelled, and whilst addressing a social sustainability issue may then have negative environmental effects.

This review has highlighted the importance of out-of-home mobility to older people, and the role that the car plays in providing that mobility at present. There is an acceptance of technological support, but limited enthusiasm (at present) by older people for CAV as a solution to their needs, but at the same time it is possible to see that some groups (women and those in rural communities) will continue to face reduced mobility in later life. Although there is an awareness that for many they will need to reduce, moderate and potentially stop driving, there is little forward planning to cope with this eventuality. It is perhaps then beholden of those that will go on to develop CAV solutions that they also ensure that older people are sufficiently engaged with and considered in the design approach to bridge the current gap between a problem and potential solution.

4 References

- Abraham, H., Lee, C., Brady, S., Fitzgerald, C., Mehler, B., Reimer, B., & Coughlin, J. F. (2016) Autonomous vehicles, trust, and driving alternatives: A survey of consumer preferences. MIT AgeLab White Paper No. 2016-6. Massachusetts Institute of Technology, Cambridge, MA. [Online]: http://agelab.mit.edu/files/publications/2016_6_Autonomous_Vehicles_Consumer_Preferences.pdf
- Access Economics. (2005). Dementia Estimates and Projections: Australian States and Territories. Australian Capital Territory [ACT]: Alzheimer's Australia.
- Ahern, A. & Hine, J. 2012. Rural transport - Valuing the mobility of older people. *Research in Transportation Economics*, Volume 34, Issue 1, 2012, pp 27-34
- Alsnih, R. & Hensher, D.A. 2003. The mobility and accessibility expectations of seniors in an ageing population. *Transportation Research Part A* 37 (2003) 903–916
- Anstey, K. J., Windsor, t. D., Luszcz, M. A., & Andrews, G. R. (2006). Predicting driving cessation over 5 years in older adults: Psychological well-being and cognitive competence are stronger predictors than physical health. *Journal of the American Geriatrics Society*, 54, 121–126.
- Anstey, K. J., Wood, J., Lord, S. & Walker, J. G. (2005). Cognitive, Sensory and Physical Factors enabling Driving Safety in Older Adults, *Clinical Psychology Review*, 25(1), 45-65.
- Arentze, T., Timmermans, H.J.P., Jorritsma, P., Kalter, M-J.O. & Schoemakers, A. 2008. More grey hair—but for Whom? Scenario-Based Simulations of Elderly Activity Travel Patterns in 2020. *Transportation*, Volume 35, Issue 5, 2008, pp 613-627
- Bansal, P. and Kockelman K, C. (2016) Are Americans Ready to Embrace Connected & Self-Driving Vehicles? A Case Study OF Texans. *Transportation*. [Online]: http://www.cae.utexas.edu/prof/kockelman/public_html/TRB17TxOpinionsCAVs.pdf
- Bansal, P., and Kockelman, K. (2015) Forecasting Americans' Long-Term Adoption of Connected and Autonomous Vehicle Technologies. Under review for presentation at the 95th Annual Meeting of Transportation Research Board and for publication in *Transportation Research Part A*
- Bansal, P., Kockleman, K. M. and Singh, A. (2016) Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. *Transportation Research Part C: Emerging Technologies*, 67, p.1-14
- Barton, C., Holmes, J. and Jacobs, C. (2014) Mobility scooters : a market study. Research Institute for Consumer Affairs. [Online]: <http://www.rica.org.uk/sites/default/files/documents/pdfs/research-consultancy/Rica%20Mobility%20scooter%20market%20study%20final.pdf>
- Berg, J., Levin, L., Abramsson, M. & Hagberg, J. 2015, "“I want complete freedom”: car use and everyday mobility among the newly retired", *European Transport Research Review*, vol. 7, no. 4, pp. 1-10.
- Bradshaw, C., Di Stefano, M. & Catchpole J. 2013. Dementia and driving. Royal Automobile Club of Victoria (RACV) Ltd.
- Chihuri, S. et al (2015) Driving Cessation and Health Outcomes in Older Adults: A LongROAD Study
- Classen, S., Eby, D.W., Molnar, L.J., Dobbs, B.M. & Winter, S.M. Transportation and Ageing: Exploring Stakeholders' Perspectives on Advancing Safe Mobility. *South African Journal of Occupational Therapy*, Volume 41, Issue 3, 2011,
- Coughlin, J. T. Longevity, Lifestyle, and Anticipating the New Demands of Ageing on the Transportation System. *Public Works Management and Policy* 13, No. 4, 2009, pp. 301-311. Luis, C.A.

D'Ambrosio, L.A., Donorfio, L.K.M., Coughlin, J.F., Mohyde, M. & Meyer, J. 2008. Gender Differences in Self-Regulation Patterns and Attitudes Toward Driving Among Older Adults, *Journal of Women & Ageing*, 20:3-4, 265-282

Davern, T., Spiteri, M. and Glivar, T. (2015) Older drivers' perceptions and acceptance of vehicle safety technology. Australasian Road Safety Conference, 1st, 2015, Gold Coast, Queensland, Australia

Department for Transport (DfT). 2014. Transport Statistics Great Britain: 2013. DfT: London. [Online] www.gov.uk/government/uploads/system/uploads/attachment_data/file/264679/tsgb-2013.pdf

Department for Transport (DfT). 2015. National Travel Survey: England 2014. Average distance travelled per person per year by age group and gender: England, 2014 [NTS0612]. Statistical Release, DfT, London.

Devlin, A. & McGillivray, J. 2016. Self-regulatory driving behaviours amongst older drivers according to cognitive status. *Transportation Research Part F* 39 (2016) 1–9

Duncan, M., Charness, N., Chapin, T., Horner, M., Stevens, L., Richard, A., Souders, D., Crute, J., Riemondy, A. & Morgan, D. 2015. Enhanced Mobility for Ageing Populations Using Automated Vehicles. Florida State University, Tallahassee; Florida Department of Transportation

Emmerson, C., Guo, A. W., Blythe, P. and Namdeo, A. (2012) In-Vehicle Navigation Systems and Older Drivers. 19th ITS World Congress, ITS America

Fiedler, M. (2007) Older People and Public Transport: challenges and chances of an ageing society. Rupprecht Consulting for European Metropolitan Transport Authorities. Paris.

Freund, B. & Szinovacz, M. 2002. Effects of Cognition on Driving Involvement Among the Oldest Old: Variations by Gender and Alternative Transportation Opportunities. *The Gerontologist*. Vol. 42, No. 5, 621–633

Glass, C. J., and D. K. Flynn. Retirement Needs and Preparation of Rural Middle Aged Persons. *Educational Gerontology*, Vol. 26, No. 2, 2000, pp. 109-134.

Hakamies-Blomqvist, L; Henriksson, P; Anund, A; Sorensen, G. Baby-boomers as future older road users. VTI Rapport, Issue 507, 2005, 69p

Harper, C., Mangones, S., Hendrickson, C.T. & Samaras, C. 2015. Bounding the Potential Increases in Vehicles Miles Travelled for the Non-Driving and Elderly Populations and People with Travel-Restrictive Medical Conditions in an Automated Vehicle Environment. Transportation Research Board 94th Annual Meeting, Transportation Research Board, 2015.

Heikkinen, S. & Henriksson, P. 2013. Äldres resvanor: äldre trafikanter som heterogen grupp och framtida forskningsbehov. VTI NOTAT, Swedish National Road and Transport Research Institute (VTI), Issue 21-2013, 2013, 32p (In Swedish, translated with Google Translate)

Holley-Moore, G. and Creighton, H. (2015) The future of transport in an ageing society. ILC-UK and Age UK

Jenness, J.W., Lerner, N.D., Mazor, S.D., Osberg, J.S. & Tefft, B.C. 2008a. Use of Advanced In-Vehicle Technology by younger and older early adopters. Selected results from five technology surveys. US Department of Transportation, National Highway Traffic Safety Administration.

Jenness, J.W., Lerner, N.D., Mazor, S.D., Osberg, J.S. & Tefft, B.C. 2008b. Use of Advanced In-Vehicle Technology by younger and older early adopters. Survey results on adaptive cruise control systems. US Department of Transportation, National Highway Traffic Safety Administration.

Johnson, M. and Rose, G. (2015) Extending life on the bike: Electric bike use by older Australians. *Journal of Transport & Health*, 2 (2), p.276-283

- Joseph, D., Chavis, C & Ardeshiri, A. 2015. Estimating the Loss of Consumption Due to Driving Cessation Among the Elderly Population. Transportation Research Board 94th Annual Meeting, Transportation Research Board, 2015, 14p
- Körber, M., Gold, C., Lechner, D. & Bengler, K. 2016. The Influence of Age on the Take-Over of Vehicle Control in Highly Automated Driving. Transportation Research Part F: Traffic Psychology and Behaviour, Volume 39, 2016, pp 19-32
- Kowalski, K., Love, J., Tuokko, H., MacDonald, S., Hultsch, D. & Strauss, E. 2012. The influence of cognitive impairment with no dementia on driving restriction and cessation in older adults. Accident Analysis & Prevention, Volume 49, Issue 0, 2012.
- Kyriakidis, M., Happee, R., and de Winter, J. C. F. (2015) Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. Transportation Research Part F, 32: 127-140.
- Li, H., Raeside, R., Chen, T., & McQuaid, R.W. 2012. Population ageing, gender and the transportation system. Research in Transportation Economics 34 (2012) 39-47
- Liddle, J., Gystafsson, L., Bartlett, H. and McKenna, K. (2012) Time use, role participation and life satisfaction of older people: Impact of driving status. Australian Occupational Therapy Journal, 59 (5), p.384-392
- Llaneras, R. E. (2006) Exploratory Study of Early Adopters, Safety-Related Driving With Advanced Technologies. Draft Final Task 2 Report: In-Vehicle Systems Inventory, Recruitment Methods & Approaches, and Owner Interview Results. U.S. Department of Transportation, National Highway Traffic Safety Administration Report No. DOT HS 809 972
- Loewenstein, D.A., Acevedo, A., Barker, W.W. and Duara, R., 2003. Mild cognitive impairment Directions for future research. Neurology, 61(4), pp.438-444.
- MacArthur, J., Dill, J. and Person, M. (2014) E-Bikes in the North America: Results from an online survey. Transportation Research Record: Journal of the Transportation Research Board, DOI: 10.3141/2468-14
- Mackett, R. 2015. Improving accessibility for older people - Investing in a valuable asset, Journal of Transport and Health, vol. 2, no. 1, pp. 5-13.
- May, E., Garrett, R. and Ballantyne, A. (2010) Being mobile: electric mobility-scooters and their use by older people. Ageing Society, 30 (7), p.1219–1237
- Missel, J. (2014) Ipsos MORI Loyalty automotive survey. [Online]: http://www.ipsos-mori.com/researchpublications/researcharchive/3427/Only-18-per-cent-of-Britons-believe-driverless-cars-to-be-an-important-development-for-the-car-industry-to-focus-on.aspx?utm_campaign=cmp_325684&utm_source=getnewsletter
- Molnar, L. J., Eby, D. W., Charlton, J. L., Langford, J., Koppel, S. & Marshall, S. (2013). Driving avoidance by older adults: Is it always self-regulation? Accident Analysis and Prevention, 57, 96 – 104.
- Molnar, L.J., Charlton, J.L., Eby, D.W., Langford, J., Koppel, S., Marshall, S., Man-Son-Hing, M., 4-6 October 2012. Findings from the Candrive/Ozcandrive study: Self-regulatory driving practices among older adults. In proceedings of Australasian Road Safety. Research, Policing and Education Conference, Wellington, NZ. In Molnar et al. (2013). Driving avoidance by older adults: Is it always self-regulation? Accident Analysis and Prevention, 57, 96 – 104.
- Musselwhite, C. and Shergold, I. (2012) Examining the process of driving cessation in later life. European Journal of Ageing, 10 (2). pp. 89-100.

- Nordbakke, S. & Schwanen, T. Transport, unmet activity needs and wellbeing in later life: exploring the links. *Transportation*, Volume 42, Issue 6, 2015, pp 1129-1151
- Nordbakke, S. Capabilities for mobility among urban older women: barriers, strategies and options. *Journal of Transport Geography*, Volume 26, Issue 0, 2013, pp 166-174
- O'Connor, M.L., Edwards, J.D., Wadley, V.G., & Crowe, M. 2010. Changes in mobility among older adults with psychometrically defined mild cognitive impairment. *Journal of Gerontology: Psychological Sciences*, 65B(3), 306–316
- Office for National Statistics (ONS). 2012. Population Ageing in the United Kingdom, its Constituent Countries and the European Union
- Office for National Statistics (ONS). 2013a. General Lifestyle Survey 2011. [Online] www.ons.gov.uk/ons/rel/ghs/general-lifestyle-survey/2011/rpt-chapter-3.html
- Office for National Statistics (ONS). 2013b. National population projections, 2012-based. [Online] www.ons.gov.uk/ons/dcp171778_334975.pdf
- Office for National Statistics (ONS). 2014a UK population estimates 2013. [Online] www.ons.gov.uk/ons/rel/pop-estimate/population-estimates-for-uk--england-and-wales--scotland-and-northern-ireland/2013/sty-population-estimates.html
- Office for National Statistics. 2014b. Estimates of the Very Old (including Centenarians) for England and Wales, United Kingdom, 2002 to 2013. [Online] www.ons.gov.uk/ons/rel/mortality-ageing/estimates-of-the-very-old--including-centenarians-/2002---2013--england-and-wales--united-kingdom-/stb-2002-2013-estimates-of-the-very-old.html
- Pape, David; Agrawal, Asha Weinstein. Transportation Perceptions of Working Adults Planning for Retirement: A Qualitative Study. Transportation Research Board 93rd Annual Meeting, Transportation Research Board, 2014
- Parkhurst, G., Galvin, K., Musselwhite, C., Phillips, J., Shergold, I. and Todres, L. (2014) Beyond transport: Understanding the role of mobilities in connecting rural elders in civic society. In: Hennessey, C., Means, R. and Burholt, V., eds. (2014) *Countryside Connections: Older People, Community and Place in Rural Britain*. Bristol: Policy Press, pp. 125-157.
- Payre, W., Cestac J. and Delhomme, P. (2014) Intention to use a fully automated car: Attitudes and a priori acceptability. *Transportation Research Part F*, 27: 252–263
- Rapoport, M.J., Sukhawathanakul, P., Naglie, G., Tuokko, H., Myers, A., Crizzle, A., Korner-Bitensky, N., Vrkljan, B., Bédard, M., Porter, M.M., Mazer, B., Gélinas, I., Man-Son-Hing, M., Marshall, S. 2016. Cognitive Performance, Driving Behaviour, and Attitudes over Time in Older Adults, *Canadian journal on ageing*. Vol. 35 S1, pp. 81-91
- Reimer, B., Mehler, B. & Coughlin, J.F. 2010. An Evaluation of Driver Reactions to New Vehicle Parking Assist Technologies Developed to Reduce Driver Stress. New England University Transportation Center; Research and Innovative Technology Administration.
- Royal Automobile Club of Victoria [RACV]. (2009). *Experiences of Non-Drivers in Victoria*. Victoria: RACV.
- Schoettle, B. and Sivak, M. (2014). A survey of public opinion about autonomous and self-driving vehicles in the US, the UK, and Australia. University of Michigan Transport Research Institute, Report No. UMTRI-2014-21
- Schoettle, B. and Sivak, M. (2015) Motorists' Preferences for Different Levels of Vehicle Automation. University of Michigan, Technical Report No. UMTRI-2015-22.

- Seapine Software (2014). Study Finds 88 Percent of Adults Would Be Worried about Riding in a Driverless Car [Online]: <http://www.seapine.com/about-us/press-release-full?press=217>
- Shergold, I., Parkhurst, G. and Musselwhite, C. (2012) Rural car dependence: An emerging barrier to community activity for older people. *Transportation Planning and Technology*, 35 (1). pp. 69-85.
- Siren, A. & Haustein, S. Baby boomers' mobility patterns and preferences: What are the implications for future transport? *Transport Policy*, Volume 29, Issue 0, 2013, pp 136-144
- Sixsmith, A. & Gutman, G.M. 2013, *Technologies for active ageing*, Springer, New York.
- SIZE. Life quality of senior citizens in relation to mobility conditions. Summary of the results of Area 3. Department of Technology and Society, Lund University, Sweden April 2006
- Smith, K., Marshall, D. and Chrysler, S. (2014) Older Drivers' Acceptance of In-Vehicle Systems and the Effect it has on Safety. Mid-America Transportation Center, Report No. 25-1121-0003-217
- Su, F. & Bell, M.G. Travel differences by gender for older people in London. *Research in Transportation Economics*, Volume 34, Issue 1, 2012, pp 35-38
- The Hartford Center for Mature Market Excellence (2014) Top technologies for mature drivers: consumer insights [Online]: <http://www.thehartford.com/sites/thehartford/files/consumer-insights-infographic.pdf>
- The Hartford Center for Mature Market Excellence (2015) Vehicle technology adoption among mature drivers. [Online]: https://www.thehartford.com/sites/the_hartford/files/vehicle-technology-adopt.pdf
- Thoreau, R. (2015) The Impact of Mobility Scooters on Their Users. Does Their Usage Help or Hinder?: A State of the Art Review. *Journal of Transport & Health*, 2 (2), p. 269-275
- Truong, L.T & Somenahalli, S. 2011. Exploring mobility of older people: a case study of Adelaide. *Australasian Transport Research Forum (ATRF)*, 34th, 2011, Adelaide, South Australia, Australia, Volume 34, Issue 0060, 2011, 18p
- van den Berg, P., Kemperman, A., de Kleijn, B. & Borgers, A. 2016;2015. Ageing and loneliness: The role of mobility and the built environment, *Travel Behaviour and Society*, vol. 5, pp. 48-55.
- Vrkljan, B., Crizzle, A., Villeneuve, S., Porter, M., Koppel, S., Mazer, B.L., Naglie, G., Bédard, M., Tuokko, H.A., Gélinas, I., Marshall, S.C. & Rapoport, M.J. 2016, "Do Demographics and Functional Abilities Influence Vehicle Type Driven by Older Canadians?", *Canadian journal on ageing*. Vol. 35. S1, pp. 92-98
- Vrkljan, B.H., Cranney, A., Worswick, J., O'Donnell, S., Li, L.C. & Gélinas, I. (2010). Supporting safe driving with arthritis: Developing a driving toolkit for clinical practice and consumer use. *American Journal of Occupational Therapy*, 64 (2), 259-267
- Wasfi, R., Levinson, D. and El-Geneidy, A. (2012). Measuring the transportation needs of seniors. *Journal of Transport Literature*, 6 (2), p.8-32
- Winston N. A., and J. Barnes. Anticipation of Retirement among Baby Boomers. *Journal of Women & Ageing*, Vol. 19, No. 3-4, 2007, pp. 1-24
- Yen, I.H., Shim, J.K., Martinez, A.D. & Barker, J.C. 2012, "Older people and social connectedness: how place and activities keep people engaged", *Journal of ageing research*, vol. 2012, pp. 139523-10.
- Young, K. I., Koppel, S. & Charlton, J.L. 2016, In press. Toward best practice in Human Machine Interface design for olderdrivers: A review of current design guidelines. *Accident Analysis and Prevention*.

Ziegler, F. and Schwanen, T. 2011. 'I like to go out to be energised by different people': an exploratory analysis of mobility and wellbeing in later life. *Ageing and Society*. 31 (5).

