Maintaining safe mobility for the ageing population

The role of the private car

Box, Gandolfi and Mitchell
April 2010

RAC Foundation

The Royal Automobile Club Foundation for Motoring Limited is a charity which explores the economic, mobility, safety and environmental issues relating to roads and responsible road users. Independent and authoritative research, carried out for the public benefit, is central to the Foundation's activities.

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This report has been prepared by Elizabeth Box MA MSc MCIHT, Head of Research at the RAC Foundation. Dr Julie Gandolfi, BA (Hons.) MSc. PhD PGCPSE Driving Research Limited (with assistance from Dr Sarah Fletcher) and Dr Kit Mitchell, Independent Consultant, have provided the background papers.

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Foreword

Older people are now enjoying more healthy and active retirement years than ever before. Although a welcome development, this social trend provides challenges for policy makers in all areas, not least transport. The population of older drivers is growing particularly rapidly as this group has become accustomed to the mobility afforded by the car. Many have retired to locations that are most easily accessed by the private car and a growing proportion of older people continue to have the resources available to run vehicles.

As individuals we worry about our elderly relatives whom we know will be devastated when they are no longer able to drive. We also worry about the day when we too will be without our cars and hence lose the significant benefits they bring: easy access to family, social activities, shopping and health services. Being unable to drive can lead to isolation and increased dependency on the goodwill of others. In turn this may result in health problems and a decline in general well-being. There are also wider social costs: health and social services are more likely to have to make home visits; older pedestrians are particularly vulnerable to serious injury and death; and the extended family support network can start to break down.

It is in everybody's interest that people are encouraged to remain independently mobile as long as they are safe to do so.

There is much work to be done to understand how best to achieve this. The three papers in this volume offer a contribution. They demonstrate the dangers of making policy on the basis of anecdote rather than proper analysis. They also illustrate what interventions might be beneficial for older people's mobility and safety, some of which can be implemented at relatively little cost. These include: giving more attention to the needs of older drivers (and indeed the rest of the driving population) when designing vehicles and road infrastructure; offering positive help, advice and training to older drivers and to those they share the road with; taking greater care with the way the authorities frame and administer the criteria that determines ability to drive; and giving more attention to the alternatives that can be made available when driving a car is no longer possible.

In publishing these papers, having discussed their contents with many of the leading experts in the field, the RAC Foundation seeks to promote further research into this rapidly growing issue and hence improve the introduction and implementation of policy.

The ultimate aim is to preserve mobility and enhance the general quality of life of this rapidly growing sector of society without compromising safety. There is a great deal to be done.

Stephen Glaister

Professor Stephen Glaister CBE
Director
RAC Foundation

About this report

This collection of papers entitled 'Maintaining safe mobility for the ageing population: The role of the private car' was commissioned as a follow-up to the 2009 RAC Foundation report 'The Car in British Society', which was awarded the Herbert Crow Memorial Award from the Worshipful Company of Carmen in 2010 for contemporary knowledge-enhancing achievement.

The UK, like its European neighbours has an ageing population and the implications of this trend for transport and mobility pose difficult questions for policy.

This RAC Foundation report has been developed to inform and encourage debate on the topic of safe mobility in old age in general and the role of the motor car in particular. It is hoped that practitioners and policy makers from a number of disciplines, not only the field of transport, will find the papers useful in both current and future debates on the subject.

The report is presented as follows:

- Older drivers: An RAC Foundation perspective *Elizabeth Box MA MSc MCIHT, Head of Research, RAC Foundation.*

Background papers

- Paper 1: Older Drivers: A review
  Dr Kit Mitchell, Independent Consultant
- Paper 2: Infrastructure and older driver risk: A literature review
  Dr Julie Gandolfi BA (Hons) MSc PhD PGCPSE, Driving Research Limited

About the authors

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Head of Research, RAC Foundation

Elizabeth Box is Head of Research at the RAC Foundation, an independent charity established to promote for the public benefit research into environmental, economic, mobility and safety issues relating to the use of motor vehicles.

Since joining the RAC Foundation Elizabeth has been responsible for commissioning a large programme of research addressing taxation, mobility, safety, environmental and road performance issues. She has spoken both nationally and internationally about UK transport policy. She has also presented RAC Foundation views to Government and Parliament on a range subjects including school travel, learning to drive, older people's mobility, traffic signage, road network performance, road safety compliance and future transport policy.

A transport planner by training, Elizabeth has an MA in Geography from Trinity College Cambridge, an MSc in Transport planning from Oxford Brookes University and is an elected member of the Chartered Institute of Highways and Transportation. Both the Transport Planning Society and De Havilland have presented Elizabeth with awards in recent years for her success in the fields of research and campaigning.

Before the RAC Foundation Elizabeth worked for Buckinghamshire County Council as a Transport Policy Officer, responsible for accessibility planning, the Local Transport Plan and market research.

Dr Julie Gandolfi BA (Hons.) MSc. PhD PGCPSE

Julie has a background in Psychology, with undergraduate and Masters degrees in the subject. She gained a PhD from Cranfield University for research relating to psychometric assessment of police driver risk. She has worked as a part-time Research Consultant for Cranfield University since 2004, participating in projects commissioned by organisations including Nissan, the European Commission, Balfour Beatty and Unilever. Julie also lectures on Cranfield postgraduate degree courses including the MSc in Driver Behaviour and Education and the MSc in Automotive Systems Engineering. In 2007 Julie founded Driving Research Ltd., specialising in the development of psychometric risk assessments for specific road user groups, and consultancy to Local Authority Road Safety Teams on the development and evaluation of road safety initiatives.

Dr Kit Mitchell

Dr C G B (Kit) Mitchell worked at the British government Road Research Laboratory/ Transport Research Laboratory from 1970 to 1994, on public transport, including the Cabtrack and Minitram automated systems and Dial-a-bus demonstrations in the mid-1970s; on transport planning and the effects of transport policies on different groups of people; and from 1982 as Head of the Environment Division. From the early 1980s he also ran TRRL's research on transport for disabled people. He led the group that drafted the first DPTAC specification for local buses in 1988, was involved in setting up the Mobility Advice and Vehicle Information Service (MAVIS) and managed the research that produced Door to Door and Ins and Outs (A guide to car choice). He co-chaired the TRB Committee on Accessible Transportation and Mobility 2003-09, and is a member of the TRB Committee on the Safe Mobility of Older Persons. He was the recipient of the William G Bell Award for services to accessible transportation in 2001 and has lectured on accessible transport in Germany, Croatia, Malaysia, Thailand, India, Viet Nam and Japan.

Currently Dr Mitchell is providing the statistics database and helping to write the British Institute of Advanced Motorists 'Motoring Facts', and assisting UNDP improve the accessibility of public transport in Penang State, Malaysia.

Older drivers:
An RAC Foundation perspective

Elizabeth Box MA MSC MCIHT
Head of Research
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Executive Summary

What impact will the UK's ageing population have on the provision of public services?

The UK's ageing population is having a fast growing impact on the provision of all services, including transport. Today 16 per cent of the UK's population is over the age of 65, and by 2033 it is predicted that older people will make up almost a quarter of all UK residents. This increase will be proportionately greater amongst the 'oldest old': those aged 85 and above (ONS, 2009a). The effect of these changes on the nation's driving habits will be significant.

The policy implications of this demographic change are not straight forward. There is not 'one' ageing population for services to cater for as there is a significant difference between older people who stay healthy and have the resources to remain active in retirement years and those who do not. A large proportion of older people tend to have more energetic and busy lives than previous generations and it is likely that future generations of retirees will demand a great deal more from the services and systems they use.

How important is mobility in old age?

Mobility in old age is essential to an individual's well-being. Older people, like the rest of population, rely on being able to access a wide range of services, to fulfill the requirements, and rise to the opportunities of daily life. Their need to travel is not just about accessing services. Keeping socially connected to friends and family is also important for providing a good quality of life. In the 21st century, many requirements can be met locally, but travel to destinations beyond the local area continues to be an aspiration. Research soon to be published by the Independent Transport Commission (Dargay, 2010) confirms that older people continue to travel long distances (of which 80 per cent is by car), though at a declining rate.

Decades of land-use planning promoting out-of-town developments has made it all the more important for people to drive and to continue driving, especially in areas not well served by public transport. Shopping, personal business, health and social needs are increasingly being met online, but there is a limit to their take up by a generation less familiar with internet technology than their children.

Medical advances and improved health in older age is also allowing people to drive for longer and, as families are more geographically dispersed, and communities less close knit, individuals are increasingly relying on their own personal transport to meet travel needs. This is of particular concern to the increasing number of elderly people, particularly women, who live alone.

There is no evidence to suggest that older people's desire to travel will decline at the same rate as their ability to drive or to find other options. In fact, a loss of independent mobility in old age can lead to mental and physical decline (Marottoli *et al*, 1997), which burdens both the individual and society. Maintaining independent mobility in old age, providing it is safe to do so, is of fundamental importance. If access to services and social contacts is curtailed, people may find they are cut off from the very aspects of life that made their retirement years so much better than those of previous generations.

What role does the car play in older people's mobility?

It is well known that a large proportion of people continue to drive well into old age. Three out of four adults between the ages of 60-69 have a driving licence, which is higher than the adult population as a whole. Fifty-two per cent of those aged 70 and over hold driving licences. This figure is currently lower than the rest of the population, but will increase as younger people, many of whom will have been driving throughout their adult lives, reach retirement age.

The distance travelled and the number of journeys made reduce with age, but the number of trips made for personal business and visiting friends remains steady or increase in importance. Contrary to popular belief, the car is the most used mode of transport for older people. The car accounts for 63 per cent of all trips made by those over the age of 70: 38 per cent as a car driver and 25 per cent as a car passenger. Walking is the second most important mode of transport accounting for 21 per cent of all trips.

How safe are older drivers?

The car is undoubtedly important for facilitating mobility in old age, but there are often concerns about the safety of older drivers behind the wheel. In fact, today's older drivers are no less safe than their middle age counterparts. The misconception that the elderly are dangerous when behind the wheel is a function of their overrepresentation in the casualty statistics – older motorists do not tend to have more accidents but their frailty means that they are more likely to be seriously hurt or killed when they do.

Until the age of 80, older drivers are only at greater risk of injury for every mile driven because frailty increases with age. It is only when drivers are over the age of 80 and / or travel less than about 2,000 miles a year that there is any type of increased risk due to driving ability. There may be an increased risk for drivers with certain illnesses although the effect of conditions such as progressive dementia has yet to be conclusively proved.

Older drivers bring a number of positive attributes to the road – wisdom, strategic thinking and less risk taking (O'Neill *et al*, 1999) - all of which tend to be under-appreciated by other road users. Older drivers do not present a particular threat to other road users and if involved in a collision they are more likely to injure themselves. Instead it is young male drivers who are most likely to be involved in road collisions (DfT, 2009a) and cause the highest level of risk to other road users (Clark *et al*, 2007). Older drivers tend to drive more conservatively, prefer longer gaps for entry into traffic situations and tend to avoid taking part in distracting activities whilst driving. However, collisions at intersections especially when turning right are particularly prevalent amongst this group.

What age-related impairments do people suffer and what impact does this have on their ability to drive?

As people age, physical, cognitive and visual declines set in but the time of onset, and the severity of the impairments, differ from person to person. Where driving is concerned there are three types of decline that have a measurable impact on driving ability and safety (Gandolfi, 2010):

- Physical - Restricted joint movements, such as the head and neck which can cause difficulty in scanning the road environment, or turning the steering wheel;
- Cognitive - Difficulties in processing information which can lead to an older person needing to take longer to gather the information required to make a decision; and
- Visual - Age-related sight problems such as cataracts and tunnel vision.

None of these age-related impairments automatically mean that driving is no longer appropriate. There is a great deal that can be done with education, training, medical and practical advice to ameliorate some of these conditions.

Do we need changes to driver licensing?

Licensing procedures in the UK currently state that at the age of 70 drivers must reapply for their licence and declare that their eyesight and other medical conditions are such that they can continue to drive safely. The renewed licence is normally valid for three years.

Britain has one of the safest road systems in the world for older drivers so the current driver licensing system based on self-certification appears to work well on an informal basis. The RAC Foundation believes this model should be continued with modifications.

The majority of older drivers self-regulate their driving behaviour, and will not drive in circumstances where they feel uncomfortable. But problems do arise when people are not able to comprehend their own limits.

Re-testing at age 70 is often discussed as a way to address this concern. Where age-based testing has been introduced in other parts of the world it has not necessarily improved road safety. Instead, the tests have been more likely to reduce licence holding and mobility since people fear having to re-qualify for their driving licence. Retesting at 70 may also contravene prospective legislation associated with the 'Equality Bill' as the Government Equalities Office consultation (GEO, 2009) on the subject suggests that different treatment based on age should only be permitted where it can be objectively justified. Where older drivers are concerned, age *per se* is not directly linked with increased risk, which would put mandatory testing at 70 at odds with this prospective legislation. At age 80 there is some indication that the risks are greater, but testing is unlikely to be the most acceptable or appropriate route for engaging with those who continue to drive at this age. It is for these reasons that the Foundation would not support a system of retesting for older drivers in the UK.

Where licensing is concerned the RAC Foundation recommends that:

- Licence renewal at 70 should continue as a mechanism for prompting drivers to consider their health in relation to their driving. This should be extended to include all drivers through the 10 yearly photo card renewal process;
- Restricted licensing should not be adopted in the UK for the over 70s as it would be costly and prohibitive for mobility, with at best minimal safety benefits. Restricting licences by time of day and distance from home would also be difficult to enforce and may add to driver confusion and concern; and
- Education and training for older drivers alongside insurance incentives based on risk should be adopted instead to build older drivers' capabilities for self -regulation.

Mitchell (2010) makes clear that in European countries where stricter licensing regimes exist, the safety record of older drivers is not better. All the evidence suggests that aged based testing of either medical condition or driving skills has no positive effect on road safety. Where these schemes are implemented mobility tends to be damaged, as otherwise competent older drivers give up their driving licences for fear of being tested.

How can drivers who do not effectively self-regulate their driving be identified?

In a self-certification licensing environment it is difficult to identify those drivers who fail to regulate their driving behaviour appropriately. There are a number of options available to address this concern.

- Greater engagement with the medical profession

A GP, family member or friend can provide advice and / or refer individuals to the DVLA or one of the UK mobility centres for assessment, if there is a concern about an individual's ability to drive; but this is not a fail-safe system. GP's and opticians are largely willing and able to provide information to patients about their fitness to drive (Hawley,

2010) which makes the medical based screening process for fitness to drive largely appropriate, although health practitioners have indicated that additional training on actual responsibilities and legal implications would be helpful. Some family members of older drivers have also reported that additional advice and guidance from the GP would be helpful.

The problem comes when driving ability is not necessarily affected by a specific medical condition, but due to gradually reducing capabilities (cognitive skills, visual acuity or physical mobility), which for older drivers is likely to be linked with the ageing process.

- The development of capability testing

Where medical diagnosis or on-road testing are not appropriate or available, capability testing may be used to test a driver's field of vision or other attributes associated with driving. In countries where tests for capabilities and impairments have been used, the evidence suggests that no one test can accurately describe an individual's capabilities, which can in the worst case lead to false negatives, leading to the removal of licences without good cause. Further research will be needed to assess whether it would be possible or desirable to move from a medical condition-based assessment to a capability-based assessment for safe driving throughout the lifecourse.

- Required education and training

Alongside optional education and training it may be appropriate to require older drivers who have been involved in an injury or damage-only collision to undertake mandatory training. This would require co-operation with insurance companies, but may serve in providing additional support to those at risk. The insurance industry potentially has an additional role to play through providing products which would encourage travel at low risk times and on low risk routes, as was the case with the now withdrawn Aviva and Norwich Union Pay-As-You-Go Insurance scheme.

Identifying non-compliant drivers – be they uninsured, unlicensed or drink or drug drivers – is always difficult and further work will be needed to establish how best to identify older motorists who fail to self-regulate their driving behaviour. This must however be developed in the spirit of supporting the responsible majority.

What can education and training do to improve older drivers' skills?

Providing education and training for older people is a good way to keep this group independently mobile for as long as they are willing and able. Driving is associated with three levels of behavior - strategic, tactical and operational (Smiley, 1999) - all of which can be addressed by training to improve an older driver's safety and mobility options.

In the UK there is no nationally coordinated programme for improving the road skills of older drivers. The Driving Standards Agency (DSA) has an 'Arrive Alive Classic Scheme' which provides materials for over 50s groups who request information and/or a visit from a DSA driving instructor. A number of workshops on driving theory are available at a local level from transport authorities, some of which include an element of one-to-one on-road training in the areas where the older person would like to improve his or her skills. The Institute of Advanced Motorists (IAM) has also recently launched a DriveCheck 55 programme and associated older driver report emphasising the importance of road user education (IAM, 2010).

For education to be effective the DSA, DVLA and DfT, working with bodies such as the IAM, should establish appropriate course content based on the available research evidence and publicise course availability more widely, to both older drivers and their families, possibly alongside age 70 licence renewal notices. Ultimately, courses should encourage people to assess and improve their skills. Experience from other countries as set out in this report provides a useful starting point for developing education programmes.

The road safety benefits of training schemes have been little researched, but there is evidence to suggest that they are well received and helpful to older people. Participants in existing schemes tend to be self-selecting, meaning that those who do not perceive a gap in their skills, and could benefit from some retraining, do not often apply for courses. Education programmes undoubtedly have most impact when targeted at high risk older drivers who, as a group, as already detailed, are difficult to identify.

The recent DfT consultation 'A Safer Way: Consultation on Making Britain's Roads the Safest in the World' (DfT, 2009a) pledged to 'create a culture of continued and lifelong learning'. Education and training for older drivers will need to be developed within this overall context.

How can developments in technology help?

Vehicle design improvements are developing at an unprecedented rate to meet both environmental and road safety challenges, alongside customer requirements. There is a great deal that can be achieved through vehicle design to improve the safety of older motorists, passengers and pedestrians. Changes may range from accounting for the greater frailty of the ageing population, through intelligent airbag and seatbelt designs, to making the physical and cognitive requirements of driving less demanding. Developments such as rear-view monitors, blind spot mirrors and automatic parking are also proving helpful. Ergonomic design, which allows easy access to vehicles for older drivers and their passengers, will be an increasingly important design consideration as the older market grows. Reducing headlight glare from new vehicles will also be needed as the number of older drivers with age-related eyesight concerns increases on UK roads. This is particularly important with the recent introduction of EU legislation requiring all new vehicles to be fitted with Day Time Running Lights as standard from 2011. The implications of this development on older driver vision needs to be more fully explored.

It is increasingly possible to provide dynamic information about road surfaces allowing drivers to assess driving conditions. Satellite navigation systems can already be used to compensate for slower reaction times by giving advanced warning of turns and lane changes. In the longer term, intelligent speed control could also help to prevent drivers jumping give-way and stop signs, as well as prohibiting other drivers exceeding speed limits: behaviour which can make junctions more difficult for older drivers.

These innovations can have some disadvantages: new vehicle technologies can actually increase the cognitive workload making the task more complex and possibly less safe for older drivers. It is therefore essential that older driver requirements are carefully considered if the full benefit of new vehicle technologies is to be realised for this group. If vehicle technology is developed with older drivers' needs in mind, it is likely that there will also be benefits for the rest of the population with regard to ease of understanding and use.

Can changing our road network make older drivers safer?

Surprisingly little attention has been given in the UK to the impact road design could have on making the roads safer for older drivers. As with vehicle design, engineering roads which are easier for older drivers to understand will, in many cases, lead to a driving environment which is safer for all road users. The financial costs associated with designing roads in this way can be high, but such improvements will be increasingly cost-effective as the number of people over the age of 60 increases.

Fatal accidents involving older drivers generally occur in daylight, at junctions and at low speeds. Interacting with other traffic at junctions is the main risk for older drivers, particularly when turning right across traffic (Gandolfi, 2010). As a group they are also more likely to be involved in rear-end shunts. Therefore in general terms, the more complex road environments are, the higher the accident involvement for older drivers.

'Self-explaining' roads which include perceptual cues are needed. For this to be achieved, guidance similar to that already available in the United States would need to be developed. Improvements that would specifically help reduce collisions involving older drivers include:

- Signals at junctions;
- Clear and unambiguous signage;
- Lower risk traffic control devices such as roundabouts at identified risky junctions;
- Reduced speed limits on priority roads approaching high-risk junctions;

- High contrast white lines;
- Increased luminance of signs; and
- Larger road signs.

This is a 'quick win' area, in which many of the benefits are likely to extend beyond older drivers to the rest of the driving population. The implications of changes for other road users would need to be fully explored but providing these were found to be positive and beneficial, minor road infrastructure improvements could be introduced with significant gains for road safety. Providing good quality guidance to road traffic engineers and planners on road network design for the older driver should be made a priority.

Are alternative transport modes available to allow older drivers to retire from driving?

If an older driver is no longer able to drive or decides to retire from driving, it is vital that the service delivery options and alternative transport modes are in place to support this change. These need to be in place before an older driver makes the decision to retire from driving, and ideally they should be systems that the individual has already used or is familiar with.

In rural areas where public transport networks often fail to provide an adequate level of service, the decision to retire from driving is made all the more difficult; and since a large number of people of retirement age decide to live in areas of low population density this compounds the problem of their access to public transport. Where available public transport has limited use in meeting the mobility needs of older people, especially those with physical and mental disabilities, as the system rarely provides the level of accessibility or flexibility required, particularly in more rural locations.

When an older person is no longer able to drive, lifts from friends and family provide a vital replacement for individual personal mobility, but this can leave many older people dissatisfied due to the actual or perceived burden they are placing on others. A network of transportation services is needed to meet the needs of this group including flexible routes, subsidised taxis, dial-a-ride, volunteers with cars, and easy-to-participate formal car-sharing schemes and high-quality pedestrian infrastructure (Suen and Sen, 1999). Provision should be user rather than supplier orientated. There is also a growing recognition that scooters and pavement vehicles will provide a transport alternative for older people for local journeys. The House of Commons Transport Select Committee is currently holding an inquiry into the subject, which will cover both the legal and infrastructure requirements of this form of transport.

Lack of funding is often cited as a limiting factor for improving the public transport offer. Since April 2008 every resident in England aged over 60 years, or registered disabled, has been entitled to an annual bus pass giving free off-peak travel on local buses anywhere in England - the cost to the public purse being in excess of £220m in 2010/2011 (DfT, 2009b). By increasing the age of eligibility for men and women to 65 by 2020 the cost of this will be somewhat mitigated, as indicated in the December 2009 Pre-Budget Report (ibid.). However the cost of providing this benefit to a more limited group remains considerable and with the trend of an ageing population this cost will increase substantially over the coming years. The cost of providing free travel and its relative merits needs to be fully debated.

If alternatives to the car are not provided to an acceptable standard there is a risk that older people will continue to drive when they should not. This is a particular issue for those living in rural or semi-rural situations rather than larger urban areas. There is also a risk that older people without appropriate travel options will become increasingly isolated in their homes. The ability of alternative transport modes to deliver suitable mobility for older people is dependent on land use planning, and earlier decisions made about home location in relation to the accessibility of services, friends and family. It is therefore crucial that conversations about service provision and mobility in old age are started much earlier in life and Government agencies have an important role to play.

How is the Government currently addressing the policy challenges arising from the ageing population?

The trend towards an ageing population, the importance of mobility and road safety implications for older drivers are well known by UK experts and Government officials, but the good work completed in theory has yet to be translated into a coherent policy for older people's mobility. Raising this issue and integrating concerns with the wider social care agenda is vital if older people are to be appropriately served.

Changes are also in progress for pension payments, which will encourage a large proportion of the population to work beyond the traditional retirement age. Today seven out of ten people travel to work by car. The implications of this working life change on transport are clear.

Conclusions

The UK has an ageing population and increasing numbers of older people are remaining independently mobile later in life. This trend needs to be fully recognised by government and appropriate policies developed. Where transport is concerned the RAC Foundation recommends the following:

- A greater focus on planning for mobility in old age
- Better integration of the policies serving older people
- Self-certification for older drivers should continue with modifications
- Driving licence re-testing at 70 should not be supported
- Licence renewal should continue as a mechanism for prompting drivers to consider their health in relation to their driving
- An accessible system of education and training for older drivers
- Identification of older drivers who do not self-regulate their driving behaviour appropriately
- The development of less complex and self-explaining roads with the older driver in mind
- Vehicles and vehicle technologies that are designed in a way that is inclusive and sympathetic to the needs of an ageing population
- Transport alternatives and options to allow older people continued mobility in later life when driving is no longer possible or desirable

1. Introduction

The UK has an ageing population. During the last 25 years the proportion of the population aged over 65 years grew from 15 per cent in 1983 to 16 per cent in 2008: an increase of 1.5 million people. At the same time, the percentage of the population aged 16 years and under decreased. This trend is set to continue for many years to come. By 2033, it is expected that 23 per cent of the population will be aged 65 and over. The fastest population increase has been amongst those aged 85 and over, also known as the 'oldest old'(ONS, 2009a).

These changing demographics are having an impact on all areas of public policy and service delivery. Transport is no exception, especially since in recent years it has been required to address the significant increase in older licence holders who continue to drive. This has been caused by three phenomena:

- Demographic change;
- An increase in the uptake of licences later in life by a cohort of drivers, including a large number of women, who had not learned to drive earlier in life; and
- Older people deciding to or needing to stay independently mobile by private car later in life.

This trend for continued use of the private car in old age has been largely motivated by the necessity to access services, which for many people are located at a distance with poor public transport links. The population's general preference for car use over public transport has also played a part.

This paper draws from the analysis and data on older drivers as presented in the two subsequent papers in this compendium and focuses on the policy implications of these findings.

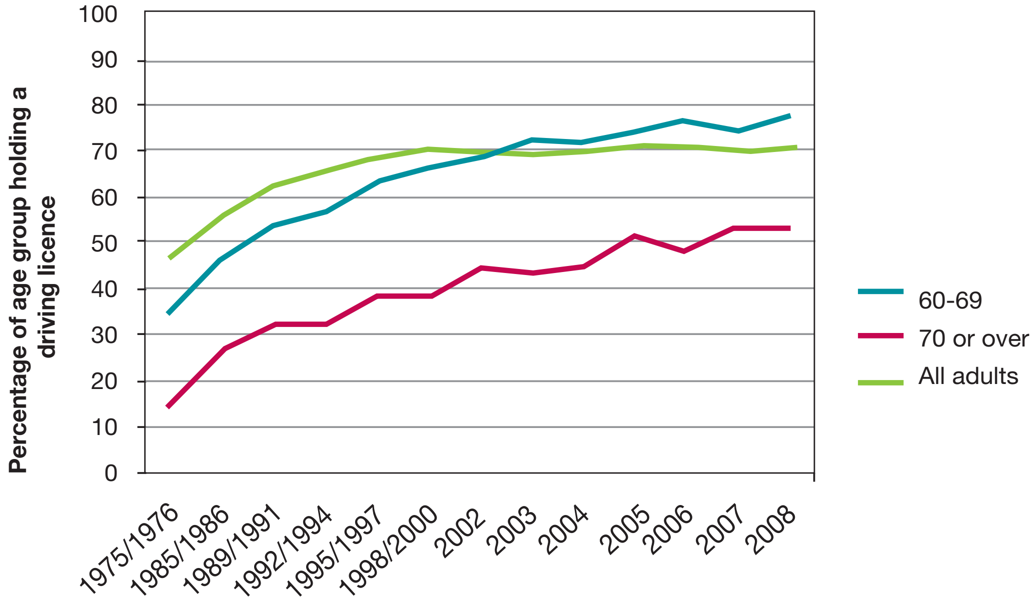
2. What we know about older drivers

There are many and various misconceptions about older drivers: both about their prevalence and safety on the UK's road network. This section sets out the facts and explores how policy options may be used to address concerns.

2.1 Driving amongst older people in the UK

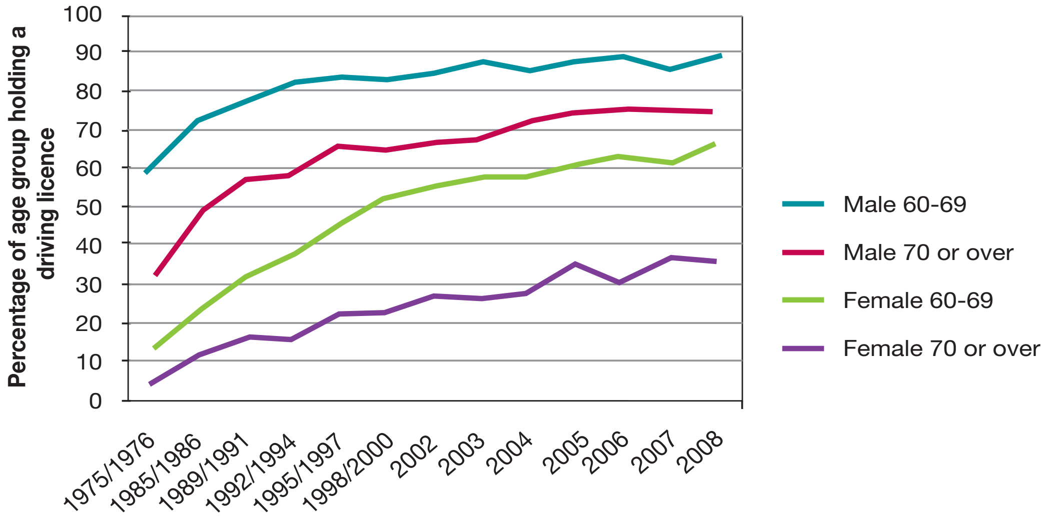
Seventy-eight percent of adults between the age of 60-69 (the younger old) have a driving licence whilst for those aged 70 and over (the old) the figure is 53 per cent (DfT, 2009e). This compares to an average for all adults of 72 per cent. Figure 2.1 shows the rapid growth in licences for older people over the past few decades. The growth in licence holding has been particularly strong for women aged 60+ as demonstrated in Figure 2.2.

Figure 2.1 Trends in full driving licence holding for the 60+ age group



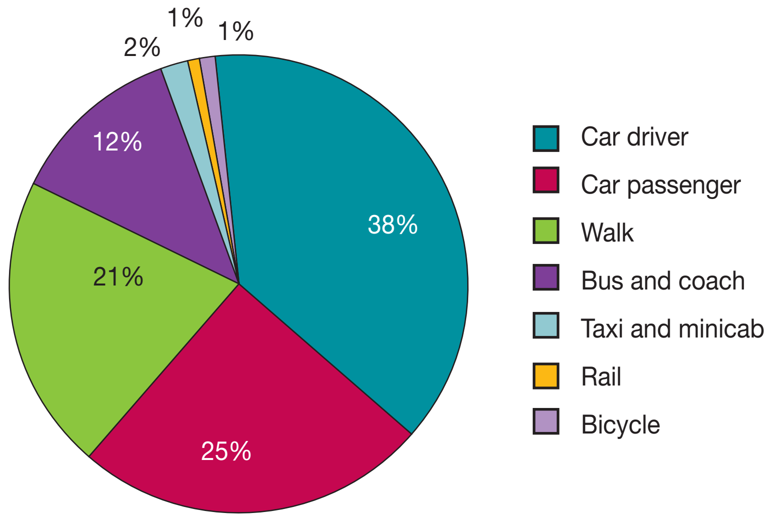
Source: DfT (2009e) Transport Statistics Great Britain. Table 9.16 Private motoring: full car driving licence holders by age and gender: 1975/1976 – 2008

Figure 2.2 Trends in male and female full driving licence holding for the 60+ age group



Source: DfT (2009e) Transport Statistics Great Britain. Table 9.16 Private motoring: full car driving licence holders by age and gender: 1975/1976 – 2008

Figure 2.3 Trips by mode of transport for those aged 70 and over



Source: National Travel Survey (2009c) Table 5.1 Trips per person per year by age, gender and main mode: 2008

Where types of journey are concerned the distance travelled and the number of journeys made reduces with age for both men and women. Men travel further than women throughout their lives. Up until age 50 women make more trips than men, after which men make more journeys (Mitchell, 2010).

Journeys for work and education reduce as age increases whereas trips taken to visit friends remain important to those aged 75 and over. Shopping and personal business journeys increase after retirement and so does the number of non-work journeys. There are no initial indications that transport difficulties are reducing people's activities although, as identified by the Social Exclusion Unit (2003) 'Making the Connections: Final Report on Transport and Social Exclusion', access inequalities can occur.

The car remains by far the most important mode of transport for older people (see Figure 2.3). Sixty-three per cent of all trips by those aged over 70 are as car driver or car passenger, and a further 21 per cent are made on foot.

Men make more of their journeys as a car driver than women, who are more likely to be passengers. On average, people over the age of 70 will travel about 2600 miles a year by car (as a driver or passenger) and each trip made by car or other means is on average 5.6 miles long, in comparison to almost 7 miles for the rest of the population. The number of car journeys made decreases with age, partly because there is a reduced percentage of the older driving population holding driving licences and partly because those with driving licences are driving less. A focus group of older drivers, recently convened for RAC Foundation research, revealed that although the cost of motoring was an issue for older drivers it was considered an essential part of the household budget in return for the value the car provides. There was also a reasonably high level of resistance to moving home to reduce any existing reliance on the car.

> *"When you get to our age that's the most important thing, you haven't got long left, you want to get as much pleasure and do what you want to do… You don't want somebody taking it away from you and as long as you can afford to do it, you're going to do it, you'll give up a lot of other things before you'll give up your car."*
>
> Male participant, over 75s group, Banbury
> Lucas, K. and Jones, P. (2009) The Car in British Society
> Prepared for the RAC Foundation

2.2 The safety of older people behind the wheel

Due to failing health, reduced confidence or slowed reaction times older people may be considered less safe behind the wheel than their younger counterparts. This is often the position presented by the media and a number of stories have been published about older motorists who appear not to be fit to drive.

> **Pensioner, 89, killed in head-on collision after driving wrong way down dual carriageway**
>
> By Daily Mail Reporter
>
> *"An 89-year-old man has died after he drove the wrong way down a dual carriageway and smashed into a van.*
>
> *Terrified drivers swerved to avoid the Ford Ka, as it sped down on the A12 near Ardleigh in Colchester, Essex, at 8pm last night.*
>
> *Police were scrambled to the scene but discovered the car had already crashed head-on into the Renault van.*
>
> *The elderly motorist was pronounced dead at the scene, while the van driver was taken to hospital with serious injuries".*
>
> Source: Daily Mail Online, 25th January, 2010

From the evidence available it is possible to deduce that older people are as safe behind the wheel as the rest of the population. Contrary to popular belief the majority of older drivers have good driving records. Up to age 80, most older drivers appear to perform as well as middle-aged motorists and after this age only a small minority of active older drivers, often travelling less than approximately 2000 miles per year, are at an elevated risk on a per mile basis (Mitchell, 2010). The fatality rate per driving licence increases with age because as people get older they become increasingly frail, and so are more vulnerable to injury when involved in an accident. Older drivers are in fact involved in fewer slight accidents than younger travellers, but a disproportionate number of older travellers are killed in road accidents due to frailty. Drivers also tend to reduce the distance they travel as they get older, which increases the casualty rate per mile driven for the group.

As older drivers increase as a percentage of the driving population it is likely that other drivers will get used to their driving style resulting in reduced collision rates for older drivers.

It is also important to understand what risk older drivers pose to other road users. One way to measure this is to assess the number of pedestrians killed by drivers of different ages. This analysis shows that young men, and men generally (due to higher mileage travelled and a higher casualty rate per mile driven) pose a greater risk to pedestrians than older drivers (Mitchell, 2010). However, older drivers do tend to have a higher proportion of collisions with younger drivers aged 17-25 than their middle-aged counterparts. Even so, rather than being more dangerous drivers *per se*, it appears that older drivers are simply more likely to make errors that are not easily dealt with by younger drivers.

There is a difference between the frequency of collisions amongst male and female older drivers, which is an extension of the trend seen for all age groups. Men are more likely to be injured in a road collision, which is due to both the higher mileage travelled and the greater propensity to take risks. Both male and female drivers become more safe as they become more experienced, and where collisions do occur in older age they tend to be more closely linked with poor judgement of driving conditions, which is where refresher training would prove a useful intervention. Discussions with older people reveal women are more likely to feel nervous about continuing to drive and, again, some updating of skills at the right time could improve confidence within this group.

> *"I'm almost afraid of stopping driving for fear that I don't want to start again."*
>
> Female participant, over 75s group, Banbury
> Lucas, K. and Jones, P. (2009) The Car in British Society
> Prepared for the RAC Foundation

For older people the risk per journey as a pedestrian is much higher than their risk per journey as a car occupant and therefore careful thought should be given to the potential unintended consequences of encourageing older people to walk instead of drive.

2.3 The effects of ageing and their impact on driving ability

It is well known that visual and cognitive performance for driving-related tasks diminishes with age. Older drivers have measurable increases in impairments but up to age 80 they are not involved in a higher rate of accidents (Mitchell, 2010). It is when involved in a road collision that older drivers are more susceptible to serious injury, often due to pre-existing health conditions and general physical fragility.

The age-related impairments suffered by older drivers fall into three key categories:

- Physical;
- Cognitive; and
- Visual.

Physical impairments include restricted mobility and joint movements, particularly of the head and neck. These can prevent drivers from adequately scanning and checking their surroundings in the driving environment. There may also be problems in turning the steering wheel.

Cognitive age-related declines refer to the difficulties experienced with processing information. It will often take longer for an older person to gather the information required to make a decision on situations that present themselves on the road. Age-related sight problems can prevent the recognition of important road features such as signage and marking.

Despite these known age-related declines, age alone is a poor indicator of performance since abilities and effects differ from person to person. Instead, it is important that the challenges faced by many older drivers are recognised, and where possible, the driving environment is made easier to negotiate by those who continue to be fit to drive. The majority of older drivers are successful at self-regulating their driving behaviour, whilst those who do not are most likely to cause problems. Policies should be developed to suit the mobility needs of both groups.

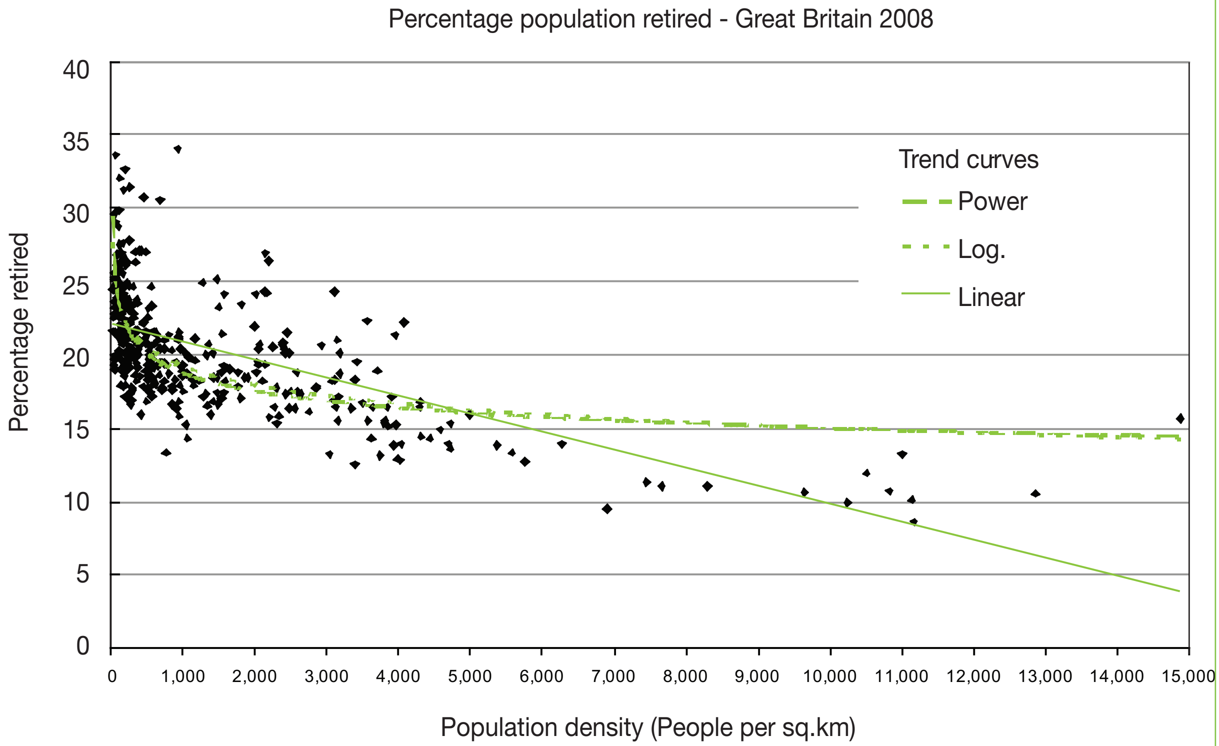
> *"When I get to the stage where I'm not driving, my whole existence will collapse because myself and my wife - (dancing) it's our main hobby."*
>
> Male participant, over 75s group, Banbury
> Lucas, K. and Jones, P. (2009) The Car in British Society
> Prepared for the RAC Foundation

2.4 The mobility consequences of reducing or stopping car usage in old age

Mobility is essential to the quality of life of older people in Britain and the car is the primary means of meeting that need: a trend set to continue as the UK's population ages. Independent mobility is important to older people, important enough that many individuals feel it worth putting themselves at higher risk of injury by continuing to drive as they become more physically frail.

Evidence demonstrates that people of retirement age are more likely to live in lower density areas less well served by public transport (see Figure 2.4) meaning that many older people have self-selected to be more reliant on their cars. There is also evidence to suggest that when people move during retirement they often intend to make two moves, one to a quiet rural area and a final move to a more accessible urban location (Musselwhite, 2006). The problem comes when people are unable to make the final move and find themselves in a remote location with few mobility options.

Figure 2.4: Percentage of population retired by population density (Great Britain)



Source: ONS (2009b) Regional Trends 41

> *"You can't rely on other people, if you want to shop at our age, you don't want to walk miles to it. In the country, you really do need a vehicle, a lot more than in the town."*
>
> Male participant, over 75s group, Banbury
> Lucas, K. and Jones, P. (2009) The Car in British Society
> Prepared for the RAC Foundation

Loss of personal independent mobility can lead to mental and physical decline, including depression (Marottoli *et al*, 1997). It has the potential not only to burden individuals, but also their social and wider society support system. To maintain good personal health it is important to keep the older population independently mobile for as long as possible, although this must be done with road safety in mind.

The RAC Foundation's recent report, 'The Car in British Society', tested the views of various focus groups on car usage and the mobility consequences of reducing its use. Results confirmed that car owners put a high value on the freedom and independence offered by the car, as well as being able to access a wide range of goods and services. Public transport was considered largely outside personal control and many of those without cars were still largely reliant on car owning friends or family to provide transport to the places they needed to go. This sometimes led to people feeling burdensome and isolated.

On the subject of the relevance of public transport:

"You can get to town alright, but Sainsbury's is a mile and a half that way, Tesco's is a mile and half the other way. There's no supermarket in the centre of town."

Male participant, over 75s group, Banbury
Lucas, K. and Jones, P. (2009) The Car in British Society
Prepared for the RAC Foundation

2.5 The role of self-regulation in old age

Self-regulation is one way in which older drivers can change their driving habits with positive benefits for road safety. Although there is no quantitative data available on the extent to which older drivers in the UK currently self-regulate their driving, it is a technique that is already considered to be widespread.

Older female drivers reduce the number of car journeys they make about twenty years before their male counterparts, which has been anecdotally linked to women's greater preference to avoid stressful driving situations. However, women are not more likely to surrender driving licences at younger ages than male drivers.

"To be honest, it's my age. I feel like I've become a little bit of a coward, of getting in it sometimes and taking it very long distances whereas I used to do much longer journeys. I'm a little bit frightened of driving too far."

Female participant, over 75s group, Banbury
Lucas, K. and Jones, P. (2009) The Car in British Society
Prepared for the RAC Foundation

Once drivers reach the age of 70 they are more likely to change their behaviour to avoid certain situations. Sixty-two per cent of this age group have reported avoiding busy times on the roads (Simms, 1993). Older drivers are also more likely to avoid driving at night, especially during rain. As a group they also reduce the distances they travel, avoid motorways and confine car journeys to well known routes. The fact that older drivers alter their driving habits, or cease driving altogether to avoid the problems faced, is broadly positive for road safety, but it presents concerns for the mobility afforded to this group.

In the UK the official policy on older drivers' licensing is self-certification. This requires drivers from the age of 70 to declare their eyesight and other medical conditions are such that they can continue to drive safely. This approach is in essence self-regulation and whilst some may relinquish car keys at the expense of their mobility, there will be others who will continue to drive when they are incapable of doing so safely.

> *"I do take great pleasure in driving until something happens and then it will suddenly destroy my confidence."*
>
> Female participant, over 75s group, Banbury
> Lucas, K. and Jones, P. (2009) The Car in British Society
> Prepared for the RAC Foundation

Britain has one of the safest road systems in the world for older drivers, so the current driver licensing system works well on a self-assessment basis. The majority of older drivers self-regulate their driving behaviour, and will not drive in circumstances where they feel uncomfortable. Against this background, the problem comes when people do not effectively comprehend their own limits.

3. The policy options

At present, there is no overall policy for addressing the current and growing numbers of older drivers on UK roads. Whilst it is recognised that older drivers should not be considered a threat to the safety of others on the road, it is true that this group is at higher risk of death and injury if involved in a collision. It is also true that significant mobility and access problems would present themselves if it were decided, for example, to require those over the age of 70 to relinquish their driving licences.

Until now, action by the government on older driver licensing has been cautious. In the early part of this decade several initiatives involving older drivers were commissioned by the Department for Transport (DfT, 2001; Holland *et al*, 2001; Rabbitt, 2002). These reports tended to focus on older people's general mobility and physical difficulties, with only more recent work looking at the infrastructure needs of older drivers (Clarke *et al*, 2009).

The Government's two most recent and relevant policy documents: 'Delivering a Sustainable Transport System' (DfT, 2008b) and 'A Safer Way: Consultation on Making Britain's Roads the Safest in the World' (DfT, 2009a), made only cursory mention of the subject, focusing on changing socio-demographics, older pedestrian vulnerability and car occupant frailty, rather than infrastructure requirements.

> *"While we expect population growth to continue, we are becoming an older society. Historically, older drivers have made fewer and shorter trips, but today older people are increasingly likely to own cars and continue driving longer"*
>
> DfT (2008b) Delivering a Sustainable Transport System, p.24, Section 3.4

> *"The number of older drivers has increased over the past decade and is expected to continue to increase during the next. Not only are there more older people with a driving licence, but there has also been a marked increase in the distance they travel. Older drivers tend to have lower bone density and slower recovery times from injuries. This means the same type of accident can cause more serious injuries, and can be more debilitating"*
>
> DfT (2009a) A Safer Way:
> Consultation on Making Britain's Roads the Safest in the World, p.58

The subject of older drivers covers a diverse range of interested parties including DfT, DVLA, DSA, NHS Trusts and care providers amongst others. Addressing this policy area more fully in the future may not focus on transport alone as the delivery of local services becomes more important. Some of the potential policy options are presented below for discussion.

3.1 Driver licensing

In the UK an individual's driving licence entitlement expires when they reach the age of 70. If they decide to continue driving, the entitlement needs to be renewed by the Driver and Vehicle Licensing Agency (DVLA). The renewed licence is normally valid for three years and is issued to applicants who self-certify their ability to meet DVLA medical requirements. There are no additional driving examinations to take.

Some commentators argue that more stringent testing procedures are needed to ensure older motorists' safety.

Once the Equalities Bill, currently before Parliament, receives Royal Assent it is unlikely that testing based on age will be developed in the UK as it will only be possible to 'allow different treatment based on age only where it can be objectively justified' (GEO, 2009, p.9). Where older drivers are concerned age *per se* is not directly linked with increased risk, which would make testing at 70 an inappropriate policy going forwards.

Studies on the licence renewal procedure for older drivers date back to the 1980s, and most of them suggest that more stringent tests for licence renewal by older drivers do not improve road safety (Mitchell, 2010). Instead, the tests are more likely to reduce licence holding and mobility since people fear having to re-qualify for their driving licence. The evidence therefore suggests that testing based on age, should it be permitted, is likely to be counterproductive both from a road safety and mobility perspective.

Other European countries practice a wide range of car driving licence renewal procedures. The countries with the most relaxed licence renewal processes, and the least demanding requirements for medical examinations (France, United Kingdom, the Netherlands and Sweden) have the highest level of driving licence holding for people over the age of 65. The United Kingdom and the Netherlands also have the lowest fatality rate per population for car drivers aged 65+ with Sweden the fourth lowest. Case study examples of the European experience are provided in more detail in the second paper contained in this compendium (Mitchell, 2010).

Licence renewal at age 70, on the other hand, provides a useful prompt for drivers to consider their health in relation to their driving. The D46P reminder application, automatically sent to all drivers over the age of 70, requires older motorists to provide details of medical conditions that may affect their driving. The same list of medical questions is set out in the D1 driving licence application form. To ensure this process is not discriminatorily based on age, it may be advisable to extend this requirement to the rest of the driving population, especially as there is no evidence to suggest that people in their 70s and 80s are more likely to exhibit certain detrimental health conditions than younger motorists. All drivers are required to inform the DVLA of any change in their health, but lack of knowledge about this requirement or fear of losing a driving licence means that many motorists do not pass on this information. The ten year photo card licence renewal may provide a good opportunity to ask motorists more regularly for this information.

It is clear that some older drivers should stop driving but experience in other European countries suggests that population screening is not the most effective way, from a road safety, mobility or cost perspective, to identify those most at risk. This then poses the important question of how to preserve the mobility of the able majority whilst accurately identifying those who should not be on the road.

One way in which this might be achieved is through giving 'restricted licences' to those most at risk to preserve both safety and mobility for the majority. The idea of a graduated licence for older drivers was initially proposed by Dr. Patricia Waller and is described in her technical paper on licensing of older drivers for the landmark Transportation Research Board publication, "Transportation in an Aging Society" (TRB, 1988). A number of countries and organisations, such as The American Association of Retired Persons (AARP) support the introduction of restricted licences for older drivers (Molnar *et al*, 2007).

A study for the North Carolina Governor's Highway Safety Program (Stutts *et al*, 2000), which reviewed the effectiveness of this approach, found that only 2.1 per cent of North Carolina's licensed drivers aged 65 and above had a restriction other than corrective lenses on their licences. The most frequent restrictions (other than corrective lenses) are 45 mph/no interstate and daylight driving only. An analysis of the road safety implications of the scheme found that drivers with restrictions other than corrective lenses had higher crash rates than drivers with no restrictions or corrective lenses only. The reason for the higher rates could not be determined from the data available, but there was some indication that many of the specialised restrictions were being imposed by the State's Medical Review Board and not by licence examiners in the field. If this was the case, drivers may have had certain medical conditions that increased their crash risk, masking any potential safety benefits of restricted licensing.

More recently, research from British Columbia (Nasvadi *et al*, 2009), found the opposite effect. This study found that the risk of causing a crash was 87% lower for restricted drivers compared with unrestricted drivers after controlling for age and gender. The most common restriction was a combination of daylight driving only plus a speed maximum of 80 km/hr. It was found that restricted drivers retained a driver's licence for a longer period of time than unrestricted drivers and continued to drive crash free longer than unrestricted drivers. There was no difference in the severity of collisions, and the results suggest that there was a high level of compliance with daylight-only restrictions.

The North Carolina study in comparison found that many older people were unaware of the availability of driving restrictions other than for corrective lenses; and many were unaware - or unwilling - to acknowledge the restrictions placed on their own licences. One-third of the drivers who admitted to having a restriction other than corrective lenses disagreed with their restriction and/or felt it made it harder for them to meet their transportation needs. Men were especially likely to feel this way. Regardless of their feelings, eight out of ten drivers claimed that they always complied with their restrictions, illustrating that compliance amongst this group was high. Many of the older people questioned admitted to voluntarily restricting their driving to reduce crash risk, with over half saying that they avoid night time driving, high speed roadways, driving in heavy traffic or on unfamiliar roadways, and driving on long trips or in bad weather. Older females were most likely to self-restrict. Eight out of ten older drivers agreed that restricted licences might help some older drivers and was something that the majority of older drivers would comply with and accept. However, they also felt more information was needed on restricted licences.

The Second European Driving Licence Directive (and the forthcoming Third European Directive which will take effect from January 2013) contains provision for the issue of restricted licences in the UK, but this has not been adopted due to concerns about how enforceable the provision is and its potential mobility and safety consequences. Restricted licences in the UK are provided on a medical basis, for instance requiring modified vehicles for drivers with limb impairments, but any further restrictions would need to be capability based as all drivers need to meet the required medical standards. The techniques available for capability testing, such as field of vision tests, and their implications for a full assessment of fitness to drive has yet to be conclusively proved, meaning than any restricted licensing process would most likely require on-road testing. As this may be difficult to implement solely for drivers over the age of seventy, due to the equality implications already mentioned, any retesting regime would need to be implemented for the whole driving population. This is likely to be costly and prohibitive for mobility with few additional benefits for road safety. For these reasons a formal restricted licensing system, especially when the vast majority of older drivers self regulate their driving behaviour appropriately, is likely to be inappropriate.

Medical fitness to drive is difficult to define and it is often reported that doctors feel great unease when making decisions on the subject. A court case in the United States concluded that medical doctors had a key role to play in identifying unfit drivers (Gray *et al*, 2002) and that they should:

- Be targeted by a campaign that teaches the importance of discovering a patient's driving status and then including that information in the patient's file; and
- Participate in developing and validating a diagnostic screening tool to identify patients who require more extensive testing of their ability to drive.

The case also concluded that government should rely more on non-physicians, such as occupational therapists, to help identify unsafe drivers. A recent survey of health practitioners in the UK (DfT, 2010) found the majority of GPs and other health professionals were aware of the DVLA guidelines on medical aspects of Fitness to Drive (FTD) with 80% saying that they had consulted them in the past two years. The guidelines are most commonly used in relation to patients with epilepsy, visual impairment, diabetes, cardiovascular disorders and those who have suffered a stroke. The majority of health practitioners viewed providing information about FTD as part of their role. Contrary to earlier studies, a large majority of GPs did not believe that discussing FTD with patients would have a negative effect on their relationship with patients. When providing driving advice to patients not all health care professionals' recorded this in the medical notes, which could have important legal implications in the event of a road incident. The majority of health professionals also felt that there was a need for more training on giving advice to patients about FTD, with continuing professional development (CPD) courses being the most preferred source. Overall it is nurses and optometrists who were most likely to say that it was extremely important that they personally gave driving advice to patients.

The UK's current licensing system works well in comparison to those adopted by other nations, but there are undoubtedly ways to improve the system further. Licence renewal at age 70 provides a useful prompt for drivers to consider their health in relation to their driving and this could be extended to other parts of the driving population. Greater emphasis should also be given to the role of self-regulation. Educating individuals generally and older drivers specifically to recognise their own driving limitations and adapt their driving accordingly will be important. This is likely to be a much more suitable route than restricted licensing which would have limited safety benefits at the expense of mobility.

3.2 Systematically addressing the impact of road design

Surprisingly little attention has been devoted to how road design could make roads safer for older drivers in the UK. In fact, in making roads safer and easier to read for older drivers, it is likely that roads will be safer for all road users. The implications of road design are comprehensively reviewed by Dr Julie Gandolfi, in the third paper of this volume (Gandolfi, 2010), but some of the pertinent policy issues are reiterated here.

There are a number of issues, unique to older drivers that prove problematic in a variety of traffic situations. Older drivers, as has already been described, can have visual problems as well as difficulties in processing information at speed, which can lead to confusion and errors whilst out on the road.

There are two solutions to this problem: adapting the traffic environment to meet the needs of the older driver or equipping the older driver to deal with the existing traffic environment more efficiently. Both approaches are of course important, but as improvements to the road infrastructure for older drivers are likely to benefit all drivers, the cost effectiveness of this approach becomes significantly attractive, adding weight to the argument for a change in approach.

Little research has been undertaken in this area to date. Where research has been completed, it primarily focuses on the dangers experienced at junctions. During the commissioning of this compendium of papers, the DfT published its report 'Collisions Involving Older Drivers: An In-depth Study' (Clarke *et al*, 2009). This report will contribute to the debate which the Foundation hopes will inform road design guidance in due course. As demonstrated by both Dr Julie Gandolfi's and the DfT's comprehensive papers on the subject, this is an area with significant road safety benefits.

3.2.1 Locations of older driver risk

Research in the UK indicates that fatal accidents involving older drivers generally occur in daylight, at junctions, and at low speeds. Eighty per cent of fatal collisions involving drivers over the age of 65 occur when individuals in this group emerge inappropriately into the traffic stream, illustrating that the main risk for older drivers is interacting with other traffic at junctions. Single vehicle crashes account for less than 7 per cent of all older driver collisions and older drivers are far more likely to be represented in collisions occurring at less than 30mph.

The more complex road environments are, the higher the accident involvement for older drivers. Older drivers negotiate junctions according to their familiarity with the situation and based on whether they are more used to urban or rural road environments. Contrary to popular belief, especially amongst older drivers themselves, this group in fact experiences less risk when using motorways because they are less complex environments.

3.2.2 Reducing older driver crash risk at junctions

Junctions are highly complex road environments that require greater levels of attention and information processing in comparison to other situations. Junctions are the most common road accident environment for all driver groups across the world; and for older drivers with less effective visual scanning and checking procedures the dangers are exaggerated. Problems at junctions generally involve visual issues and include failure to observe relevant traffic signs or signals, traffic approaching on a priority road or failure to judge the speed and distance of oncoming vehicles.

Significant improvements could be made to this environment to improve the safety of older drivers. Collision rates for older drivers are much higher when traffic controls are not present. Currently the majority of traffic control devices at junctions are not effective in preventing older drivers from proceeding in unsafe environments. When drivers reach the age of 75, more than 50 per cent of their fatal collisions involve proceeding when traffic signals indicate it is not safe to do so. Large lens traffic signals have proved effective in this regard where they have been implemented in the US.

When turning right at junctions older drivers are five times more likely than others to move into the path of a vehicle approaching from the right. By the very nature of this type of collision older drivers are more likely to be struck on the driver's side of the vehicle.

In the first instance improvements could be made by ensuring that signage is both clear and unambiguous. At identified risky locations it may also prove beneficial to implement lower risk traffic control devices such as roundabouts. Reducing speeds on priority roads approaching high-risk junctions is also worth investigating. Negotiating junctions safely is not only about infrastructure, as successful negotiation also depends on familiarity and informal rule compliance, indicating that there is also a role for education in improving these manoeuvres.

3.2.3 Roadway curvatures and older driver safety

High bend frequency is not as risky for older drivers as negotiating junctions because risks rise for this group when dealing with other traffic. However, older drivers are at a higher risk of being killed in a collision occurring in a rural rather than urban setting due to the speeds involved, a fact mirrored throughout all age groups.

Certain types of bend such as very sharp bends which require a significant speed reduction or those which do not have very clear perceptual information are likely to present a risk to older drivers, although the comparative risk for older and younger drivers in these situations still remains unclear.

Additional perceptual cues such as advanced warning signs, advisory speed limits and chevron markers would be helpful to all road users. Rumble strips although helpful, do in fact cause significant discomfort for a number of older drivers and therefore should be used sparingly. Where overtaking occurs, older drivers are less likely to overtake dangerously, but by being over-cautious they might encourage more hazardous overtaking by others. This should be considered when designing road environments in areas where there is likely to be slow moving traffic such as farm vehicles or frequently stopping buses.

There is a great deal that can be done to actual or perceived changes in road width to prepare drivers for appropriate speed and positioning for bends. When roads are wide the driver has less perception of the speed travelled, which can have an impact on the level of deceleration when entering bends. On the other hand, narrow roads can lead to a temporary loss of visibility, making it difficult to see whether another vehicle is approaching. This can lead to drivers positioning themselves in the centre of the road, which puts them at risk of collision with an oncoming vehicle. With their reduced reaction times, this can have serious consequences for older drivers.

Where road width for bends is of concern, it has been suggested that bends can be made more forgiving by increasing the road and shoulder width. This can be beneficial for older drivers, but it can have the negative impact of increased driver speeds at the bend, which is thought to negate the overall safety gains. Drivers have been found to reduce speed more significantly for bends that are perceived as being sharper and when a combination of chevron and repeater arrow signs are used with herringbone markings on the road surface, improvements in speed reductions and lane positioning can be achieved. Improving safety for older drivers when overtaking and being overtaken is an important element of road surface design, but education in this area could be greatly improved too.

3.2.4 Roadworks and older drivers

Road-works present a high risk situation to all drivers, due to the changed nature and layout of the road. For older drivers it is important to ensure there is appropriate advanced warning of the hazard and that there is a clearly visible and interpretable path of guidance through the zone. Encouraging drivers to maintain an appropriate distance between vehicles is also important because older drivers are at greater risk of rear-end shunts. A number of best practice guidelines are set down in the DfT's (2005) 'Inclusive Mobility' guidance for this particular area.

3.2.5 The role of road markings and road width

Road markings are the most important road surface characteristics to help drivers of all ages recognise road types. When the road is well marked it can provide long-range guidance for drivers when making lane position and speed choices. Higher contrast white lines are particularly helpful for older drivers, especially in lower light conditions. As already mentioned, older drivers tend to be involved in more rear-end shunts. Merge and continuity lines can be used to keep drivers in lane when roads gain or lose a lane, which helps reduce overall speeds and overtaking rates, as well as giving older drivers more space between vehicles.

Overall, it is vitally important that a self-explaining roads philosophy is developed for older drivers who rely more heavily on perceptual cues provided by the road environment. The DfT's original 2000 paper 'Tomorrow's Roads: Safer for everyone' hinted at the importance of self-explaining roads in relation to speed and road safety and there is related advice in the DfT's (2005) 'Inclusive Mobility' guidance. There is however little evidence that this approach has been adopted by Government policy and although the post 2010 DfT consultation (DfT, 2009a) highlights the importance of developing a safe, holistic road system that takes account of road design, vehicles and users further work is needed in this area.

> *"We believe there would be real benefit in designing roads which clearly indicate by their appearance the speeds which are appropriate. Combined with the new hierarchy of roads we propose to develop, it would be another aid to explaining speed limits and persuading motorists to observe them."*
>
> Section 6.31, DfT (2000) Tomorrow's Roads: Safer for everyone

Road characteristics such as road markings, carriageway width, road signs and street furniture all act as indicators of the way in which drivers should interact with the traffic environment. The road and the surrounding environment provide essential cues for drivers to establish appropriate behavioural limits and avoid risky actions. Consistency of features across the road network is essential and should be developed further with the upmost priority.

One advantage of this approach is the potential to enhance safety for all road users. Measures to improve the road infrastructure in this way are often viewed as excessively costly and inefficient, but decisions about cost effectiveness will need to be reconsidered as the population continues to age. In addition to making expensive changes to geometric and traffic control devices, lower cost options such as increasing the luminance of signs, the size of road signs and traffic light lenses along with the reflectivity of road markings can make a useful difference.

3.3 Formalising education, training and publicity activity

General road safety education for older drivers may help to facilitate safer mobility in old age. A number of localised training programmes are in operation in the UK. These sessions are highly valued by participants but so far no scientific evaluation of their effectiveness has been carried out.

Of similar courses formally evaluated in the US (Eby *et al*, 2008), it was found that educational programmes:

- Increase the driver's knowledge and awareness;
- Increase safe driving behaviours by self report;
- Improve on-road evaluation scores;
- Do not help prevent roadway injuries; and
- May increase the number of crashes for men aged 75 years or older.

From the US experience at least it appears that although driving skills, knowledge and behaviour are improved this does not generally translate into fewer accidents. It does however seem reasonable to assume that bespoke driving courses for older drivers could sustain experience-based perceptual and awareness skills. Speed awareness courses have been found to make a noticeable improvement to people's driving behaviour, which illustrates the potential of this type of intervention. An existing OECD report (OECD, 2001) recommended that coaching interventions may be used to raise general understanding and self awareness, suggesting that this is an area, certainly for older drivers, which should be looked into further. Formalised education for older drivers is likely to help this group with appropriate self-regulation of their driving. As well as driving skills training for older drivers, there is significant value in educating those who share the road space with older drivers. Young drivers are often unsympathetic to the driving style of older drivers and can go so far as to provoke collisions in which the older driver is deemed to be at fault.

In the US, the objectives of the American Association of Retired Persons (AARP) Driver Education classes (Molnar *et al*, 2007) which generally last two days are:

- Updating driving skills and knowledge of road rules;
- Awareness of normal physical changes related to ageing, and what driving adjustments to make;
- Learning the warning signs which precede finishing with driving altogether;
- Reducing or eliminating traffic violations, accidents, and potential injury;
- Driving more safely on the road; and
- Obtaining insurance discounts. Car insurance companies usually provide discounts to AARP graduates.

Additional specific topics where older driver education would be helpful include:

- Traffic laws relating to overtaking;
- Meanings of road signs and markings;
- Providing the relevant skills to deal with difficult overtaking situations, such as failed overtakes on their part and by other drivers;
- Increasing understanding of rules at intersections and the likely informal rules in operation; and
- Increasing a driver's ability to adequately estimate oncoming vehicle speeds and make safe judgements about oncoming traffic gaps.

Older drivers have been found to have problems recognising and understanding road signs. Studies have also shown that older drivers tend to be more conscientious and are more likely to respond to signs in order to comply with the rules of the road. Education in this field could yield substantial benefits and should be considered alongside the policy changes being considered for a more life-long approach to driving education for all age groups.

3.4 Using new technologies to deliver safer mobility

Advances in technology throughout all areas of life including cars and transport are happening rapidly. There is no doubt they will play an increasingly important role in keeping older people both mobile and safe on the road. Older drivers recognise the value of 'a good car' to give them a sense of security and confidence, and new developments are thought to be helpful in providing older people with cars that are easier to get into and drive.

The potential of new vehicle technologies to deliver safer mobility for an ageing population falls into two broad categories:

- Vehicle design developments to improve safety for older car drivers, passengers and pedestrians. This may range from accounting for the greater frailty of the

ageing population to making the physical and cognitive requirements of driving less demanding; and
- Using technological advances to allow older people increased travel choices and improved access to public transport.

The ability of older people to access and make use of new enabling technologies will be central to vehicle development. Where vehicle design is concerned, manufacturers will need to be mindful that they are designing for two groups: older drivers and older passengers. This will have implications for cars other than those specifically designed to be driven by older people since many drivers will increasingly provide lifts to older friends and relatives. Communicating effectively with older drivers to ensure they are purchasing the most suitable and safe vehicles for their needs will be a challenge and should be a focus of activity.

Intelligent systems in vehicles are likely to be further developed to compensate for human weaknesses in driving. New vehicles are already effective in providing driver warnings about vehicle operation, but better intelligence about the interaction between the vehicle and road surface is still a developing area.

Age-related declines generally reduce an individual's attention span, reaction time and performance, all of which cause drivers to experience a heightened sense of workload demand. As people age, they become more easily distracted and less able to make sense of complex information. The development of intelligent and active safety systems in new cars should be implemented with an understanding of how they might affect an older driver’s capabilities as it might be that devices, developed to serve the older driver, may instead add to the cognitive workload experienced within traffic critical situations.

When properly used and understood, technology can provide significant safety benefits. Satellite navigation can help compensate for decreased reaction times by giving advanced warning of lane positioning and where to turn. Longer term, intelligent speed control could reduce speed on the approach to junctions with stop or yield signs, and on sharp bends: a system already being looked at in prototype.

Beyond ‘technology’ there are a number of areas in which vehicle manufacturers can consider older drivers’ needs. Ergonomic and product design for the emerging older driver market is one such area. There is also little research in the public domain examining how internal vehicle features such as dial design, positioning of pedals and vehicle enabled parking can assist older drivers by alleviating the known problems of reduced mobility and visibility.

Headlight design and glare are significant factors contributing to visibility related driving difficulties experienced by older people. Reducing headlight glare from new vehicles will be particularly important with the introduction of EU legislation requiring all new vehicles to be fitted with Day Time Running Lights as standard by 2011. The implications of this development on older driver vision needs to be fully explored. It is not only headlight design that should be examined but the detrimental effect of consumer alterations. Headlight alignment can cause problems for older drivers and although routinely examined in the MOT test, alignment may drift between tests. More consistent standardisation across the industry from vehicle manufacturers to maintenance and enforcement organisations could play an important role in reducing older drivers' vision concerns.

Other technology developments, such as travel advice systems which facilitate modal choice, are not specifically addressed in this compendium but they are likely to be a significant growth area, particularly with the widespread adoption of 'smart phones'. The extent to which these systems will be accessible and useful to today's older population needs to be considered. It is likely that future generations of older people who are more comfortable with using these types of systems will find them very helpful in supporting their mobility needs.

3.5 Alternative transport and service delivery options

If an older driver is no longer able to drive, or decides to retire from driving, it is vitally important that alternative transport modes and service delivery options are in place. In the majority of cases it will be essential that these alternatives are in place before the decision to retire from driving is made.

There is a significant difference between the available transport and service delivery options in rural and urban settings. In denser urban areas, public transport and walking can, and does, provide real mobility alternatives to the car. In more remote rural areas, public transport does not provide a service equivalent to the car but, surprisingly, people make almost as many pedestrian journeys in rural areas as urban areas. The fact that large numbers of older people choose to live in low density areas can be problematic. Low density urban/suburban areas provide a particular challenge as public transport could be made to work, but land use planning, including the very detailed layout of the street network, can limit the use of public transport services.

Being able to access healthcare, shopping and social needs either from home or through using the public transport system can be extremely difficult for an older population, particularly for those in rural areas or with mobility difficulties. For individuals without access to a car in areas where facilities are difficult to access, isolation can become a problem.

When an older person is no longer able to drive, lifts from friends and family provide a vital replacement for personal mobility, but this can leave many older people dissatisfied due to the actual or perceived burden they are placing on others.

In a study looking at car use by Finnish men and women over the age of 65 (Siren *et al*, 2004), it was argued that independent community-related mobility is a fundamental factor in the continued well-being of older people. Reduced mobility was found to be associated with loss of independence, reduced general activity, poorer health and increased depression. Forthcoming research in the UK has come to similar conclusions namely that '*mobility is not only important in fulfilling essential day-to-day practical needs, but also in enhancing social networks and social interaction, creating a sense of control and independence, enhancing status and role and helping people interact with nature and explore cognitive skills'* (Musselwhite *et al*, submitted)

> *"There's nothing really for the rural people in the village to do when they get infirm or elderly. They have difficulty getting on the bus, they don't have a car, they're housebound, so their lifestyle must be dreadful."*
>
> Male participant, over 75s group, Banbury
> Lucas, K. and Jones, P. (2009) The Car in British Society
> Prepared for the RAC Foundation

Buses provide a useful form of transport for some old people without access to a car, but much more reliable services are needed in many areas to provide older people with more confidence in using the available services. The quality of the waiting environment and its immediate area, which is the responsibility of the local transport authority rather than the bus operator, also needs improving in many instances. Lack of seating and lighting along with poor quality pavement maintenance can be real barriers to public transport access for older people.

Lack of funding is often cited as a limiting factor for improving the public transport offer. Since April 2008, those over the age of 60 or registered disabled and living in England have been entitled to an annual bus pass giving free off-peak travel on local bus services throughout England. In 2010/11 £223 million (DfT, 2009b) of tax payers' money will be invested in the England wide free bus fare scheme for the over 60s (increased to age 65 by 2020 following the Pre Budget Report announcement in December 2009). Concessionary fares are enshrined in primary legislation and it will be very difficult for any current or future Government to revoke the privilege, due to public support for the initiative. There is however a strong argument for this money to be reinvested in public transport at a local level in a different way.

Although the cost of public transport is a consideration for older people, the reliability and frequency of services, and the quality of the waiting environment are equally important.

Older people moving away from the private car also tend to be concerned about using public transport due to the prevalence of unfamiliar systems and the difficulty experienced in understanding timetables. Potentially there is a great deal that Government can do to improve the public transport offer to older people by reallocating the finances currently given to free travel. Making timetables easier to understand would help the population as a whole and there is also potential to aid older people with gaining confidence and skills in using public transport by providing ‘travel buddies’ for new users. It is also important to recognise that it is often the informal information about public transport services which can limit older peoples use. This group might for example like to know whether they will need to have change ready for the fare or whether they will need to share the bus with school children before making the decision to travel.

Community transport services and demand responsive transport can ‘fill the gap’ left between the car and traditional public transport services, but they tend to be expensive for the public purse and are often under used. They are also not problem-free for users.

> *“You can with a lot of difficulty get a vehicle to fetch you but it’s an all day job, it probably goes round three or four villages, when you get there you might be finished in two hours, you’ve got to wait another four hours if somebody else is in and they’re not done so it’s not really [an option]”*
>
> Male participant, over 75s group, Banbury
> Lucas, K. and Jones, P. (2009) The Car in British Society
> Prepared for the RAC Foundation

Taxis potentially provide a flexible form of on-demand transport for older people, but are little used due to their actual and perceived costs. For many older people with low annual mileages using taxis instead of the car may in fact provide an economically viable alternative to owning and running a car, but it is often difficult for this group to weigh up the broader range of options available to them.

A high proportion of all journeys completed by older people are made on foot even though older people comprise the group most vulnerable to injury as pedestrians. It is essential that pavement and crossing facilities, especially at junctions, are developed with older people in mind to ensure walking is considered a safe and viable alternative.

The DfT’s Manual for Streets (MfS) (DfT, 2007) which provides guidance on street design mentions older people in passing with regard to prohibiting footway parking, providing additional disabled parking and limiting the provision of cycle parking in areas where there is a high concentration of older people. Although the provision of benches is talked about in general terms, there is no specific mention of the needs of older pedestrians. The DfT's guidance on Inclusive Mobility (DfT, 2005), which is referred to throughout MfS focuses on the needs of the mobility impaired in response to the Disability Discrimination Act 1995. The needs of older people are only covered in general terms by this guidance. Changing the attitudes of service providers to meet these requirements is important, but unfortunately all too often limited funding for pavement repairs or concerns about street clutter do not help to meet the needs of older pedestrians.

Mobility scooters and pavement vehicles provide a form of transport which is increasingly used to replace the need for local driving. There is currently little research or available statistics about their prevalence and use, but with the UK's ageing population scooters are expected to have an increasing role to play in meeting the future transport needs of older people. This has been recently recognised by the House of Commons' Transport Select Committee which has held an inquiry on the subject. The infrastructure needs of these vehicles should be considered and the implications of their increased usage on pavement capacity and safety fully investigated. Scooters do not currently require registration and it is likely that an appropriate legislative environment will be needed to underpin their increased use. Future generations of older drivers will have higher expectations of services and the transport system. It is therefore expected that today's mobility scooters will undergo a design transformation to provide a more acceptable personal mobility system for this emerging group.

If adequate alternatives to the car are not provided under the current self-certification licensing regime there is a risk that older people will not retire from driving at the appropriate time. If people do retire from driving without the provision of suitable transport or other services, many older people will face increasing isolation.

The ability of alternative transport modes to deliver suitable mobility for older people is dependent on land use planning and decisions that older people make about home location, in relation to services, friends and family. It is vital that conversations about service provision and mobility in old age are started well before retirement. Government agencies have a particular role to play in this process.

3.6 Furthering research in older person mobility

It is clear from the RAC Foundation's initial investigations that a significant body of research is still required to inform policy on the mobility needs of an ageing population. A summary of the research areas suggested in this compendium is detailed below.

- The needs of the future ageing population

The mobility needs of future populations will be very different from today's. Further work is needed to understand more fully the expectations of the next generation of older people and how to best cater for the range of abilities amongst this group.

- The role of self-regulated driving in old age

There is a need to develop a better understanding of self-regulated driving in old age and the different needs of male and female drivers. It would also be useful to understand how education could be used to encourage more informed self-regulation.

- Motivations behind cessation of driving

Little is currently known about why older people cease driving and the relevant trigger points. A study on how many male and female drivers surrender licences, (and also stop driving without surrendering licences) would prove useful.

- Public and political appetite for licensing changes

Conditional licences, re-testing, medical declarations and lifelong learning approaches are often discussed. This report advocates some modifications to the current licensing system, but any future changes will need to be fully tested with both politicians and the electorate.

- Medical conditions and driving

The impact of medical conditions which affect cognitive skills (for example dementia) on driving need to be better understood and explained to GPs, practitioners, drivers and their families.

The interaction between multiple prescription drugs taken in older age and their implications for driving also need to be considered and communicated to drivers through education schemes developed to address self-regulated driving in old age.

- The future role of vehicles

Vehicles will need to meet the emerging needs of an ageing population. This is likely to require a great deal more research to guide vehicle manufacture. Within this context, it would be useful to establish the current and future role of mobility scooters in substituting for local car journeys and what the safety implications of their development might be.

- Evaluating the role of existing education and training for safer road use in old age

There is little evidence available to support the effectiveness of road safety education initiatives. The impact of local authority and other refresher training will need to be established before embarking on a larger programme.

- Designing future road safety and education courses for older drivers

With the known capabilities of older drivers, it is clear there are certain strategic, tactical, and operational driving skills where older drivers would benefit from re-training. Further thought should be given to how future courses should be designed with these issues in mind. Training older people to better understand the informal rules of the road and compensate for misjudgements are two such areas.

- Developing road design guidelines for the UK which reflect the needs of older drivers

This would involve investigating whether the US guidelines on highway design for older drivers would be relevant in the UK and if not, what other guidance would be required in the UK context.

- Gaining a better understanding of new drivers in older age

Some older drivers will be new drivers as a result, for example, of bereavement. After losing a spouse, women particularly may find themselves needing to drive after years of sitting in the passenger seat. As the number of older people living alone increases, it is becoming more important to understand how best to support the needs of this group and understand the difficulties they face.

- Understand to what extent older people consider their future mobility needs when they move home

At both individual and government level, lack of attention to planning for mobility in old age has compounded the transport problems experienced by older people. It would be helpful to understand to what extent people think about their mobility needs when retiring and how their decisions can be better informed in the future.

- Establish how older people adapt to declining skills in low-accessibility areas

Self-regulation has an important impact on older driver road use. Little is known about how this manifests itself across different geographical areas. How older people adapt to declining driving skills in low-accessibility areas is not known. This knowledge would be very helpful in determining the safety consequences of the UK's current licensing system.

- Consider the role of land use planning and its impact on older road users

Conventional wisdom suggests that denser residential areas and mixed-use land reduce the need to travel by car. An understanding of what a desirable land use planning framework for older people looks like is needed. It would also be useful to know to what extent cities are encouraging the location of communities in appropriate places and how much land use really matters in relation to social networks and support systems.

4. Conclusions

This report has evolved from the RAC Foundation's interest in sustaining the safe mobility of older road users. In this context, the report has considered the safety needs of older drivers and those they share the road network with. The evidence suggests that a different approach is needed as self-declared licence renewal at age 70 on its own does not deliver all that is required in today's ageing society. The RAC Foundation has the following policy conclusions and recommendations:

- **A greater focus on planning for mobility in old age**

Government and individuals tend to focus on short-term plans. Older people continuing to drive when they are unsafe to do so tends to be a product of inadequate lifespan planning by both individuals, government, and service providers. A large proportion of people in the UK retire to areas of low population density which usually requires a high reliance on the car due to a lack of local services. This puts additional pressure on older people to continue driving, possibly in circumstances where they feel uncomfortable.

As the retirement age increases and people work longer there will be serious implications for transport. Government has an important facilitative role to play both in informing individuals and directing future land use and other planning decisions with the UK's ageing population in mind.

- **Better integration of the policies serving older people**

Social structures in the UK have changed significantly over the past half-century. Generally, families are more geographically dispersed and local communities provide less of a support network. This trend is limiting the personal transport options available to an ageing population. Greater consideration should be given to how services, transport or otherwise, can better serve older people within their local communities.

The needs of older people are currently considered, assessed and planned for across a range of Government and institutional contexts. Sharing knowledge across these fields and joining up initiatives would undoubtedly be of great advantage.

- **Self-certification for older drivers should continue with modifications**

The UK has one of the safest road systems in the world, especially where older drivers are concerned. In this sense, the self-certification system for those aged 70 and over appears to have been successful and the Foundation believes this model should continue, with modifications, which are detailed below.

- **Driving licence re-testing at 70 should not be supported**

Re-testing at age 70 is often discussed as a way to filter out those who are not safe to be on the roads. However, where age-based testing has been introduced in other parts of the world it has not necessarily improved road safety. Instead, the assessments have been more likely to reduce licence holding and mobility since people fear having to re-qualify for their driving licence. For this reason the RAC Foundation would not support a system of retesting for older drivers in the UK unless it could be demonstrated that this approach would significantly improve safety without having a detrimental effect on mobility and quality of life.

Retesting based on age is unlikely to be adopted in the UK as it may contravene the provisions laid out in the Equality Bill currently before parliament. According to The Government Equalities Office consultation (GEO, 2009) different treatment based on age will only be allowed where it can be objectively justified. Where older drivers are concerned, age *per se* is not directly linked with increased risk. This would put mandatory testing at 70 at odds with prospective legislation. At age 80 there is some indication that the risks are greater, but testing is unlikely to be the most acceptable or appropriate route for engageing with those who continue to drive at this age.

- **Licence renewal should continue as a mechanism for prompting drivers to consider their health in relation to their driving**

With age-based testing being an inappropriate licensing tool, the current licence renewal requirement at 70 provides a useful prompt for drivers to consider their health and medical conditions in relation to driving. There is, however, no evidence to suggest that people are more likely to have certain detrimental health conditions at age 70 than those who are older or younger, which suggests that health condition information should be collected more regularly from all age categories.

When first applying for a driving licence individuals are required to state their medical conditions. All drivers must inform the DVLA of any change in their health, although the evidence is that motorists do not tend to contact the authorities with this information. This is because motorists either have a lack of knowledge about how or when to provide the update or because many fear the impact it might have on their ability to hold a licence. It is only at age 70, when a reminder application form is issued, that drivers are required by law to state their medical conditions and fitness to drive.

Two developments could be helpful. First, it might be appropriate to ask drivers to certify their medical conditions more regularly throughout their driving careers. Individuals are not currently required to provide information about their health when they renew their photocard driving licence every ten years. Introducing such a necessity would provide a more equitable approach to assessing driving competency and ability throughout a person's driving life.

Second, it would be helpful if more customer friendly information were available to allow people to assess the impact of their medical conditions on driving and whether it should be reported to the DVLA. This could be done via an interactive, web-based, 'decision tree' or through some sort of face-to-face contact which would allow people to discuss their vehicle and licensing requirements. There is undeniably a need to provide an additional 'friendly face' for DVLA matters to encourage greater buy-in and compliance from members of the driving public.

- **An accessible system of education and training for older drivers**

In addition to self-certified licensing, the Foundation believes there should be a more formal and accessible system of education, training and publicity to help older drivers improve their skills, develop self awareness and self-regulate their driving behaviour.

For education to be effective the DSA, DVLA and DfT, working with bodies such as the IAM, should establish appropriate course content based on the available research evidence. Ultimately the material provided would need to enable people to assess and improve their skills. In particular, there is a need to encourage older drivers to make decisions about their own driving capabilities in order that they can make informed decisions about when, and to what extent, they should restrict their driving. Courses could also help older drivers to better comprehend the informal rules of the road. There is equally the need, through separate channels, to ensure that other road users, particularly young drivers, are aware of the difficulties older drivers face and their associated driving behaviour.

Experience from other countries, as set out in this report, provides a useful starting point for developing education programmes. A number of UK local authorities independently run older driver training and it would be useful for the DVLA and DSA to work more closely with them. It might also be appropriate to provide educational information to older drivers alongside their licence renewal forms. This is likely to take the format of informing drivers what is available in their local area.

Important questions remain about how an education, training and publicity programme would be delivered; should it fall on the public or private sector to deliver it? And would the training be voluntary or mandatory at a certain age? Insurance companies might decide to require the training as a condition of providing cover. The question of who pays also needs to be fully worked through.

- **Identification of older drivers who do not self-regulate their driving behaviour appropriately**

Self-certification and education will effectively address the concerns associated with the majority of older drivers, but on their own they are not able to identify the minority of older drivers who do not, for whatever reason, effectively self-regulate their driving behaviour. This poses a number of questions about the most effective way of identifying those who do not self-regulate their driving:

- **Can inappropriate driving be traced to medical condition?** Currently if individuals are thought to be at risk a GP, family member or friend can provide advice and / or refer individuals to the DVLA or one of the UK mobility centres for assessment, but this is not a fail-safe system. Although there has been some concern that GPs are unable or unwilling to provide information to patients about their fitness to drive, a recent DfT survey found the vast majority of GPs and health professionals regard the provision of this information as part of their role. They do not generally take the view that patient / practitioner relations will be damaged by discussions about fitness to drive. Opticians also appear to be engaged with the DVLA medical guidelines and view providing information on fitness to drive as an important part of their role. The medical based screening process for fitness to drive therefore appears to be largely appropriate, although health professionals have indicated that additional training on actual responsibilities and legal implications would be helpful.

  The problem arises when driving ability is not necessarily affected by a specific medical condition, but due to gradually reduced capability (cognitive skills, visual acuity or physical mobility), which for older drivers is likely to be linked to the ageing process. The increased levels of dementia that are forecast over the next 10-15 years and the implications this has for driving create a further problem.

- **Should the focus be on capability testing?** In countries where tests for capabilities and impairments have been used, the evidence suggests that no one test can accurately describe an individual's capabilities and can, in the worst case, lead to false negatives, resulting in the removal of licences without good cause. Further research is needed to assess whether it would be possible or desirable to move from a medical condition-based assessment to a capability-based assessment for driving in older age. If capability testing were adopted this would need to be conducted by trained driving examiners, which would have financial implications for individuals and / or the government. It is also unlikely that this type of testing would be introduced for one specific group of road users, meaning that if introduced it would need to be applied across the whole driving population.

- **Should education and training be required?** In the absence of an accurate capability test it would be desirable for additional education and training to be offered, perhaps even required, to older drivers who have been involved in injury or damage-only collisions, but this raises wider issues. To do this would involve closer working with the insurance industry to help identify those most at risk.

  The insurance industry potentially has an additional role to play through providing incentive-based insurance products which would help minimise the risk to older drivers. Schemes like the Aviva / Norwich Union Pay–As-You-Go insurance scheme – now withdrawn – charged a per mile insurance premium, based on actual miles driven, varied by type of road and time of day, to reflect relative risks. Although this scheme was specifically aimed at younger drivers it could also have had a useful application for older drivers, by providing a financial disincentive to drive at times of day or on roads that were most risky.

❍ **Could conditional or restricted licences be introduced?** Conditional or restricted licences for older people have been introduced in other parts of the world with varying levels of success.

Although the Second European Driving Licence Directive (and the forthcoming Third European Union Directive which will take effect in January 2013) contains provision for the issue of restricted licences (by time of day and distance from home etc), this has not been adopted in the UK. Restricted licences are currently only given on medical grounds, for instance if an individual has a limb injury that requires a certain vehicle alteration. Providing a driver in the UK meets all of the medical fitness to drive standards they will have a full driving licence.

If restricted licensing in old age were introduced a new segment of older drivers would be identified in addition to those who have already had changes made to their licences for medical reasons. As the presence of medical conditions cannot be used to identify at risk drivers suitable for restricted licensing, capability tests would be needed, and without compulsory testing there would be no mechanism for administering the required tests. If restricted licensing for older people were to be considered desirable and appropriate for the UK it would only be possible to administer within a culture of life-long continued testing for all age groups.

A restricted licensing regime might involve restrictions such as driving at certain times of day or in certain areas. This would prove difficult to apply consistently and enforce in practice. If a driver were limited to a certain radius from their home or required to avoid motorways, any diversion could create confusion and concern. Similarly, restricting a driver with perhaps an eye condition to driving only during daylight hours could be problematic at dawn and dusk when light levels change quickly. An insurance-based approach, as already discussed, might be the most appropriate mechanism for encouraging this type of restricted driving related to risks. For these reasons it is unlikely that conditional or restricted licensing will aid with the process of safer driving in old age.

The RAC Foundation therefore recommends that the focus should be on ensuring:

- The medical professional can appropriately advise on safe driving in older age;
- Education and training is available to support older people's own self-awareness of

their driving skills and any subsequent self-regulation; and
- Improved driver education is developed for all age groups, as part of a renewed approach to lifelong learning.

Vehicle licensing and driver education are undoubtedly the central issues when looking at safer mobility in older age, but they are not the only considerations. Action also needs to be taken with regard to road development, vehicle design, in-vehicle technologies, pavements and alternatives to driving.

- **The development of less complex and self-explaining roads with the older driver in mind**

The road infrastructure can be altered to take better account of older driver needs. Older drivers are much more likely to be involved in collisions in daylight, at junctions and at low speeds. Interacting with other traffic at junctions is a significant risk, particularly when turning right across traffic.

Providing less complex and 'self-explaining' roads, which have clear signage and road markings as well as intuitive infrastructure is likely to benefit all road users, in addition to the older driver, although more work is needed on the synergies between the two. In the United States there is a 'Highways Design Handbook for Older Drivers and Pedestrians' published by the US Department of Transportation. The UK should consider developing similar guidance for the UK context to encourage innovative planning in this area. In some instances simple low cost changes, such as larger lens traffic lights, can have a significant benefit for older driver safety.

- **Vehicles and vehicle technologies that are designed in a way that is inclusive and sympathetic to the needs of an ageing population**

Traditionally, manufacturers have produced a number of vehicle models within their overall range designed for the older driver. As older people represent a growing customer base and will have higher expectations of products and services than their predecessors, manufacturers will need to provide attractive products that meet their needs.

Individual product ranges tailored for older people are unlikely to be the answer as older people do not generally want to be identified in this way through the vehicle they are driving. There is instead likely to be significant value in designing primarily with the older driver in mind, since 'inclusive design' can often benefit the rest of the driving population. There is a real danger that older people will 'opt out' of purchasing new vehicle technologies and designs due to concerns about usability. This may lead to greater safety concerns at a later point when technologies filter through the vehicle fleet onto the second hand market.

Personal mobility will continue to be important for older people and for those who are unable to continue to drive the mobility scooter may provide a viable option for continued mobility, providing it is designed in a way that meets the high expectations of this emerging population. Infrastructure and legislation will need to take this likely trend into account.

Vehicles are increasingly designed with in-car technology and systems that override human weaknesses in driving. As technological developments in satellite navigation systems, smart intersection devices, lane positioning and intelligent speed adaption control progress, the needs and difficulties experienced by older people will need to be fully considered. People become more easily distracted as they age and less able to make sense of complex information, making the development of well designed vehicle technology aids all the more important. However, vehicle technologies can have both a positive and negative effect on safety depending on whether the systems increase or decrease the mental work load of drivers.

- **Transport alternatives and options to allow older people continued mobility in later life when driving is no longer possible or desirable**

When driving is no longer possible or desirable, it is important that viable and attractive transport alternatives are in place to allow older people continued mobility in later life. After driving and travelling as a passenger, older people rely heavily on being able to walk to their destination, making it important that the pedestrian environment is welcoming and suitable.

Good pavement maintenance must be a priority, especially in areas where there is a large and increasing older population, and on the approaches to bus stops and other points of concentration. For the older pedestrian, trips and slips as well as the fear of falling become mental obstacles which can significantly limit mobility. Providing street furniture to allow for rests, along with well positioned and lit pedestrian infrastructure is important, especially at interchanges with public transport. Existing government advice in the DfT's 'Manual for Streets' and 'Inclusive Mobility' guidance indicates the importance of these developments, but more explicit mention of the needs of older people is required.

Although used by many older people, the public transport network, in its broadest sense does not provide complete mobility for this group, which presents difficulties for those who would like to retire from or reduce the extent of their driving. In rural areas particularly, there is a problem with the frequency and reliability of bus services, and other community alternatives may not be available. If older people are unfamiliar with public transport after a lifetime behind the wheel of a car, understanding how the system works can also be a significant barrier to use.

Providing older people with access to travel advisors would be useful in helping many within this group to establish the most cost-effective method of transport for their particular needs. Many older drivers who travel short distances may in fact find taxis a more economical option than the expenses associated with running a car, knowledge about this could encourage someone to feel able and confident to retire from driving.

The cost of providing free bus travel to the over 60s is considerable, and with an ageing population this will increase substantially over the coming years. The cost will be somewhat mitigated, as indicated in the Pre-Budget Report in December 2009, by increasing the age of eligibility for men and women to the age of 65 by 2020. However, even with this change the cost of the benefit will remain high and there is a strong argument for reinvesting this money in public transport at a local level in a different way. The cost of providing free travel and its relative merits needs to be fully debated.

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Background Paper 1

Older Drivers: A review

Dr C G B (Kit) Mitchell

Kit Mitchell

Summary

This review covers the mobility and safety of older drivers, comparisons between male and female drivers, licensing procedures, road design and education and refresher training. Older road users have fewer slight accidents than younger users, but a disproportionate number of older road users are killed in accidents. This is because people become more fragile as they get older, and so more vulnerable to injury. The accident involvement rate is lowest for car drivers aged 70 to 79, and only increases about 22 per cent for drivers aged 80 and over. The casualty rate per mile driven increases with increasing age much more than the casualty rate per driver. The risk from older drivers to other road users can be measured by the number of pedestrians killed by drivers of different ages. Most pedestrians are killed by male car drivers aged 50 and less.

For car drivers of all ages, the casualty rate for male drivers is higher than for female drivers. The difference is much greater for younger drivers, and rates for men and women are similar by the age of 60. Women have a higher casualty rate per mile driven than men for ages over 40, although the difference does not become substantial until the age of 60.

Studies of the effect of licence renewal procedures on the safety of older drivers date back to at least 1986. From these studies it is clear that in Australia and Europe, aged-based screening of older drivers does not improve road safety, but does reduce licence retention.

Almost all the reduction in the number of journeys people make over the age of 70 (for men) or 50 (for women) is a result of making fewer journeys as car driver. In Britain, car driving licence holding by men increased rapidly in the 1970s to 1990s, but has now saturated for men up to the age of 75. Licence holding has saturated at around 80 per cent for women in their 40s, but for all older age groups it is still increasing. The USA has produced a series of 'Highway Design Handbooks' for older drivers and older pedestrians. A number of US states have been applying the handbook since 2001. Evaluation of older driver education schemes in North America shows that they improve driving skills, knowledge and behaviour, but do not reduce crashes.

1. Introduction

This review draws heavily on a number of papers (OECD, 2001; Mitchell, 2001; Charlton *et al*, 2003; Mitchell, 2008; Eby *et al*, 2008; Mitchell, 2009) covering:

- The mobility and driving safety of older drivers;
- Comparisons between male and female drivers;
- Licensing procedures for older drivers;
- Design of roads for older drivers; and
- Education and refresher training for older drivers.

It concludes by discussing topics on which further research could be useful.

One of the first, and most influential, reports on older drivers was the US Transportation Research Board (TRB) Special Report 218 'Transportation in an ageing society: Improving mobility and safety for older persons' (TRB, 1988). It stated

"Although automobiles and highways have improved dramatically during this century, many design assumptions used today are based on the performance characteristics of a younger population. …

The roadway system - broadly construed to include street and highway design and operation, vehicle design, and driver licensing - can be better adjusted to the needs and abilities of older persons. Given the long lead time required to develop and phase in changes in the standards used for the roadway system, however, it is time to begin preparing for the mobility needs of a society that is already ageing."

The report's findings can be summarised as:

- Mobility is essential to the quality of life of older persons, and the automobile is the primary means of meeting that need;
- Most older drivers have good driving records. Up to the age of 75, most older drivers appear to perform as well as middle-aged ones;
- Older persons are among the most vulnerable to injury in motor vehicle crashes;
- In general, visual and cognitive performance on driving-related tasks diminish with age;
- Because, for any individual, age is a poor predictor of performance, age alone should not be the basis for restricting or withholding driving licences; and
- Sign visibility and maintenance standards, assumptions about performance used in intersection design and traffic operations, and vehicle crashworthiness standards fail to account for the needs and capabilities of older persons using the roadway system.

The report makes a number of detailed recommendations on signage, roadway design, vehicle safety, customer information, driver screening and licensing, and alternative means of transport.

A recent synthesis is provided by Eby *et al* (2008). It concludes:

"There are several themes that thread through this synthesis report. First, mobility is needed by all people. If mobility needs are not met by driving, then they must be met by other means. Second, older adults are not a homogeneous group. Older adults vary greatly in: the functional declines they may be experiencing; their ability to compensate for declines; their financial and social resources; and their personalities. All of these characteristics interact with the factors influencing safe mobility. Third, older adults, as well as all drivers, need lifelong education to maintain safe mobility.

For the older adult, learning about roadway design changes, how to use advanced technology, and the transportation options available when driving is no longer possible is an important component in safe mobility. Fourth, research to help older adults stay mobile will also help younger drivers."

2. Background

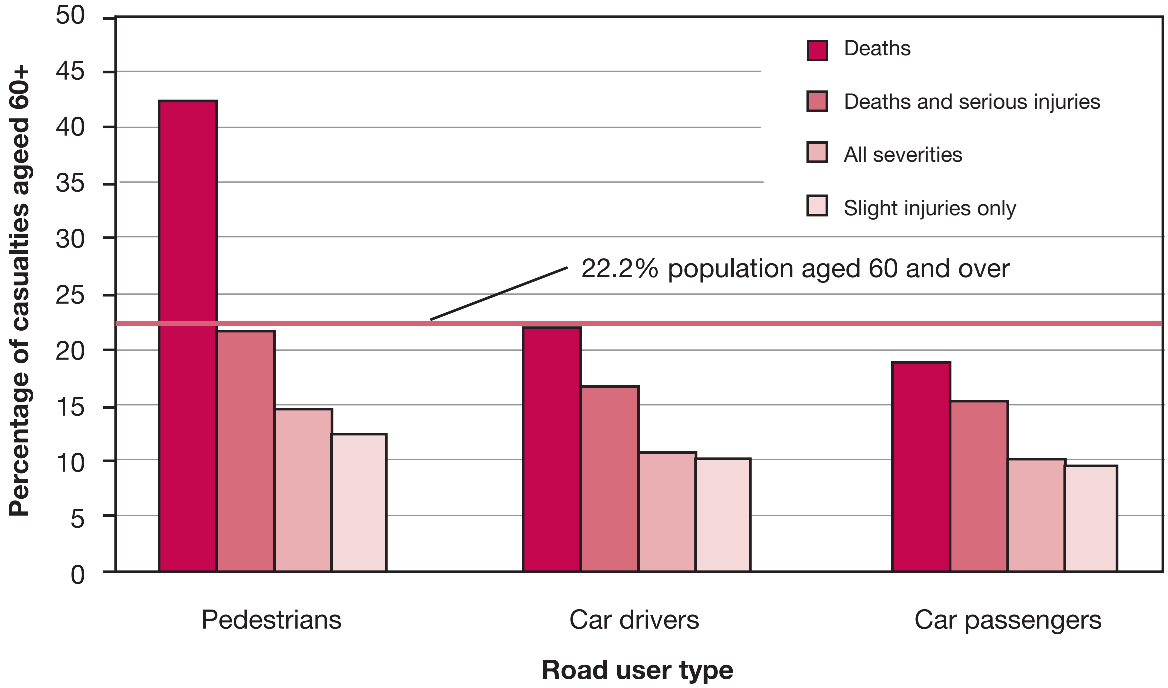
When the topic of road safety and elderly people is raised, a common reaction is that the issue concerns car drivers becoming less safe as they get older, and that the policy challenges are how to identify less safe older drivers and stop them driving. When the statistics for road accident casualties among older travellers are examined, this reaction is found to be very far from the whole story, at least in Britain. It also ignores the need of older people for mobility.

Figure 2.1 shows that older travellers have fewer slight accidents than younger travellers, because the percentage of slight casualties who are elderly is less than the percentage of elderly in the population; but a disproportionately large number of older travellers are killed in road accidents (Mitchell, 2001, updated). This applies to pedestrians, car occupants and bus passengers. Forty-three per cent of pedestrian fatalities, but only 12% of slightly injured casualties, are people aged 60 and over (who form 22.2% of the population). For car drivers, 20% of fatalities but only 10% of slightly injured casualties are aged 60 and over. For those aged 80 and over, the effect is even stronger.

2.1 Fragility

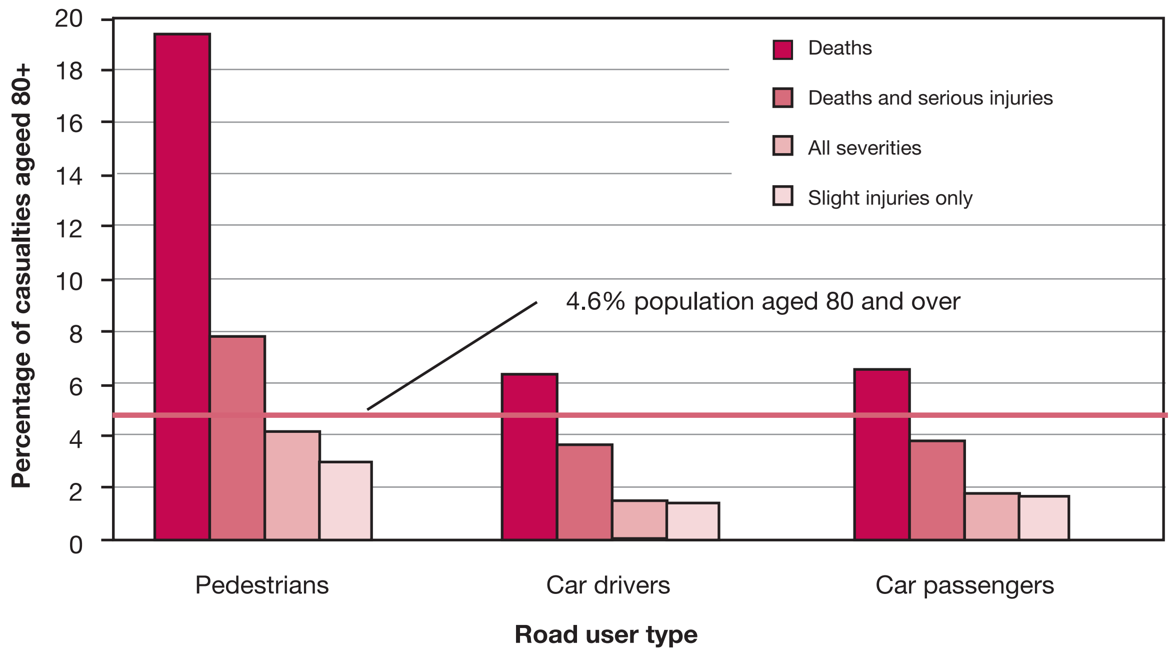
The reason that a disproportionate number of older road users are killed, despite a disproportionately small number being involved in road accidents (as indicated by the number of slight injuries) is that as people get older they become more fragile, and so more vulnerable to injury if they are involved in an accident (Figure 2.2).

Figure 2.1a Percentage of casualties aged 60 and over – Britain 2008



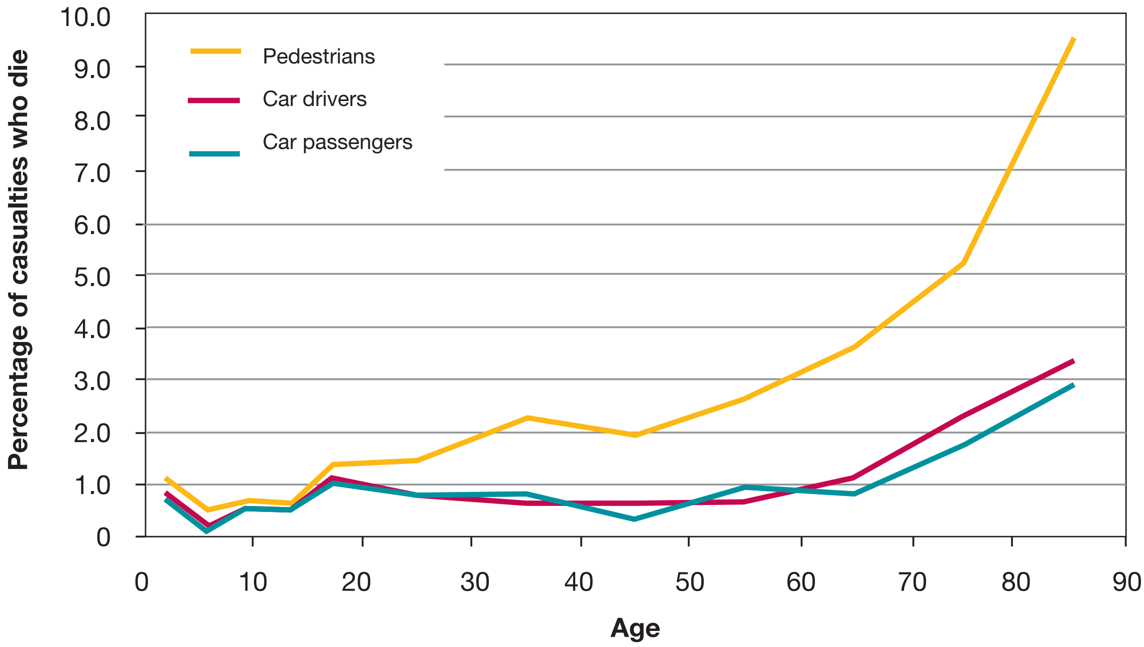
Source: DfT (2009) Road Casualties Great Britain 2008

Figure 2.1b Percentage of casualties aged 80 and over – Britain 2008



Source: DfT (2009) Road Casualties Great Britain 2008

Figure 2.2 Fragility and age, as indicated by the percentage of persons injured in traffic accidents who die – Britain 2008



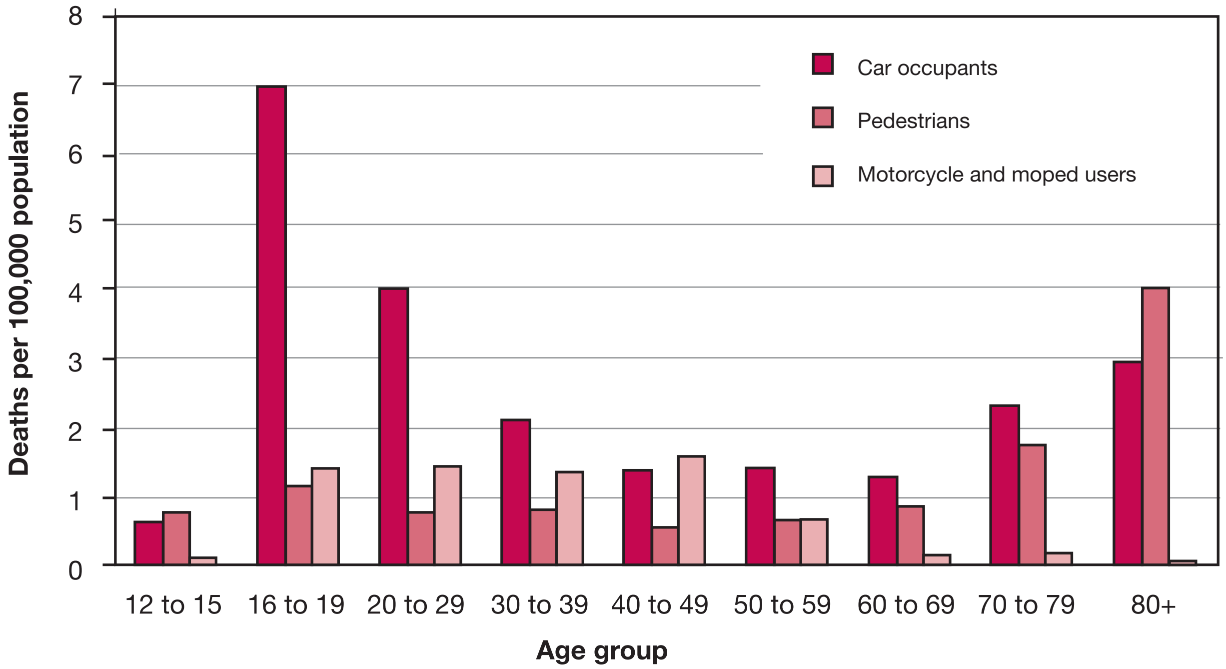
Source: DfT (2009) Road Casualties Great Britain 2008

It is important to appreciate that in terms of the number of deaths, the road safety problem for older people is as much the number of pedestrian deaths as car occupant deaths (Figure 2.3). Fourteen years ago, the number of pedestrian deaths of people aged 70 and over was double that of car occupants. By 2008, the numbers were roughly equal, due to an impressive reduction in the fatality rate for elderly pedestrians (Department for Transport, annual (a)). The rate for car occupants had reduced very slightly, despite a significant increase in the number of older drivers. By 2008, significant numbers of motorcycle user fatalities had spread to people in their 40s, a marked change from the position in 1995.

2.2 Casualty rates for car drivers

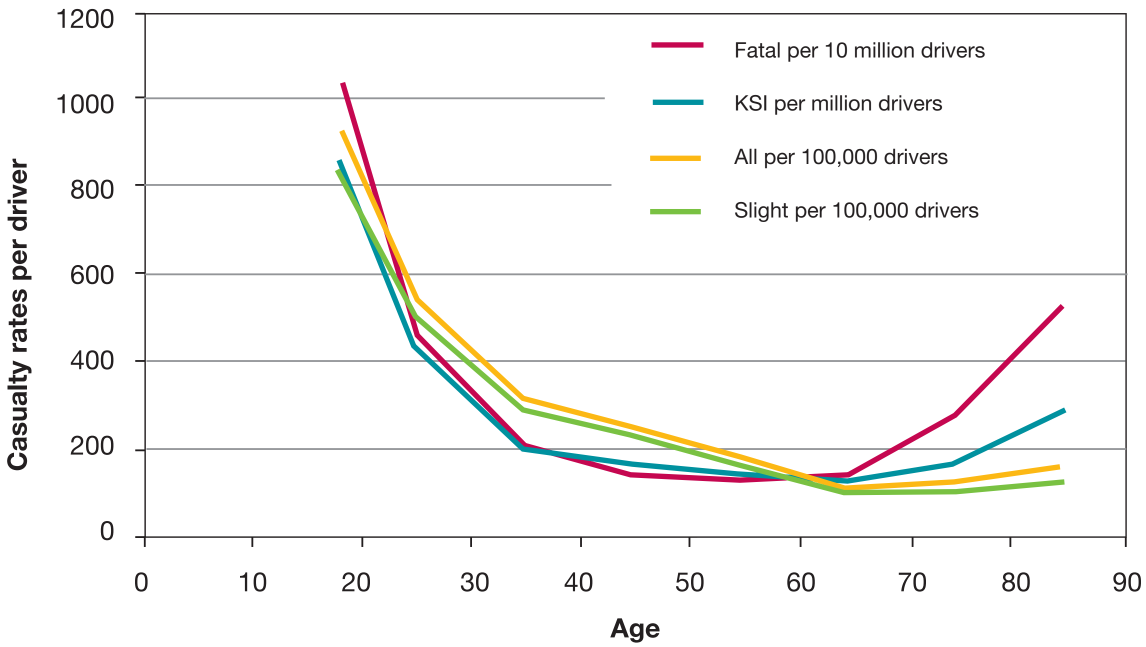
The safety of drivers can be measured as a casualty rate per licence holder, Figure 2.4. If the rate of slight injuries per licence is taken as an indicator of accident involvement, this is at its lowest rate for drivers aged 70 to 79, and only increases about 22% for drivers aged 80 and over (Mitchell, 2001 updated, using data from Department for Transport (annual) (a) and special tabulations from the National Travel Survey Department for Transport (annual) (b)). Fragility increases the rate for elderly casualties killed and seriously injured, with a lowest rate for drivers aged 60 to 69, and even more for fatalities, for whom the rate is lowest for drivers aged 50 to 59.

Figure 2.3 Fatality rates for pedestrians, car occupants and motorcycle and moped users – Britain 2008



Source: DfT (2009) Road Casualties Great Britain 2008

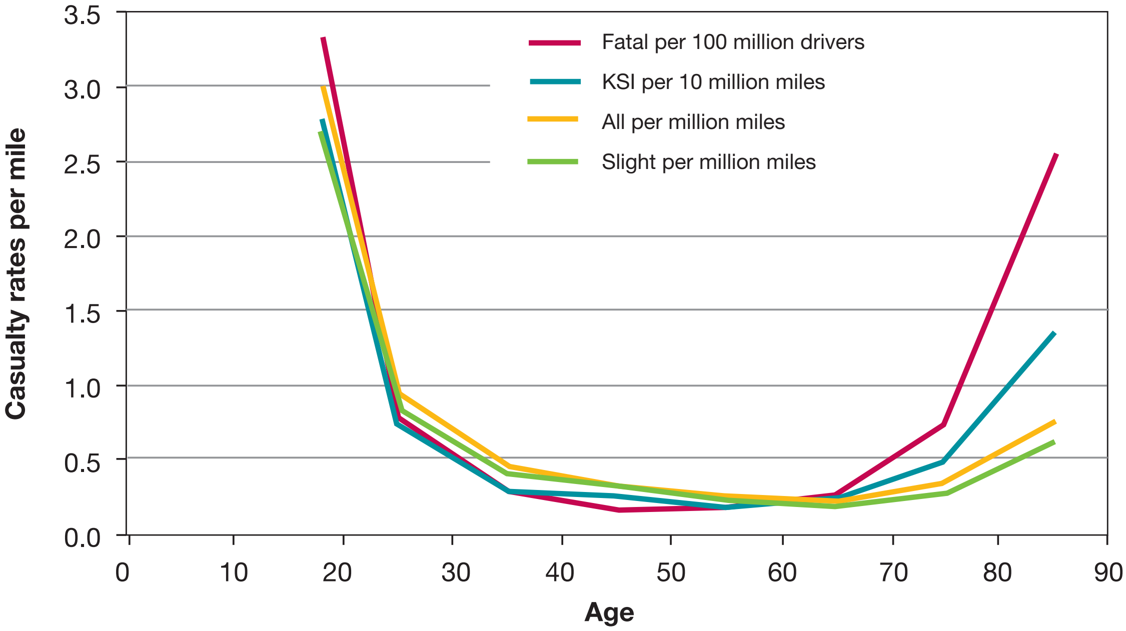
Figure 2.4 Car driver casualty rates per driver – Britain 2008



Source: DfT (2009) Road Casualties Great Britain 2008

Because drivers reduce the mileage they drive as they age, the casualty rate per mile driven increases with increasing age much more than the casualty rate per driver (Figure 2.5). Data such as this is often used to argue that older drivers are as dangerous as novice teenage drivers.

Figure 2.5 Car driver casualty rates per mile driven - Britain 2008



Source: DfT (2009) Road Casualties Great Britain 2008

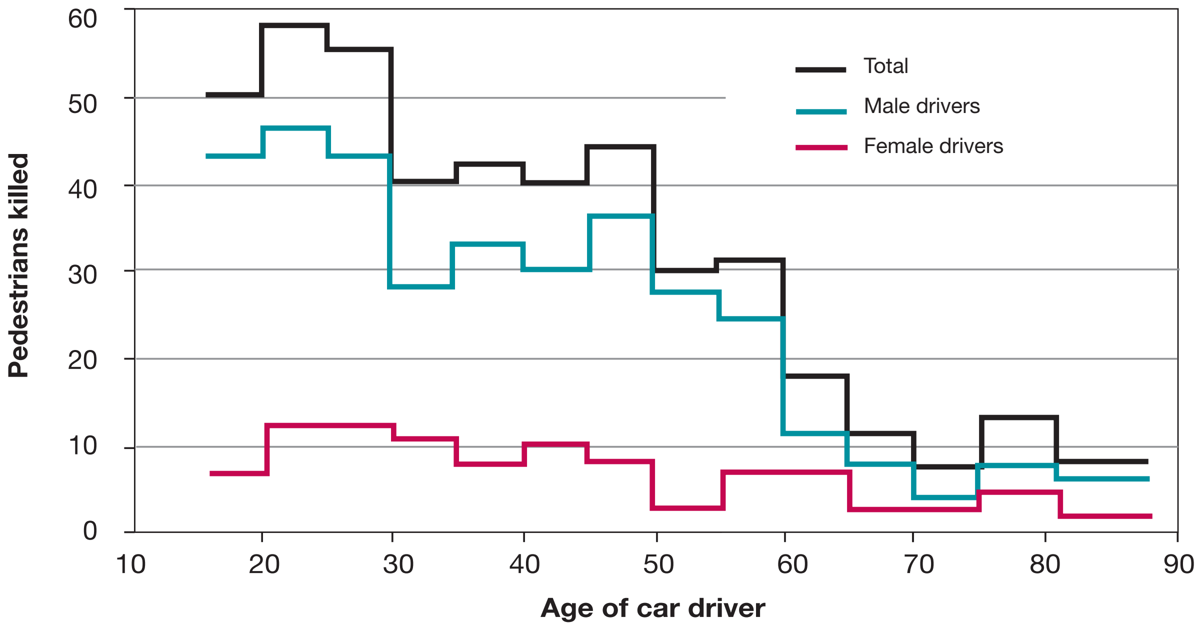
2.3 Risk to other road users

A measure of the risk to other road users posed by older drivers is the number of pedestrians killed by drivers of different ages. Figure 2.6a shows the absolute number of pedestrians killed by male and female car drivers in five year age groups in Britain in 2005 (special tabulation from Department for Transport (annual) (a)). This shows that most pedestrians are killed by men aged 50 and less.

Figures 2.6b and 2.6c show the risk of a pedestrian being killed per driver and per mile driven (derived from special tabulations from Department for Transport (annual) (a) and (b)). These emphasise the high risk to other road users caused by young drivers, particularly men aged under 30. The numbers of pedestrians killed by men is greater than can be explained by the larger number of male drivers and the distance that they drive.

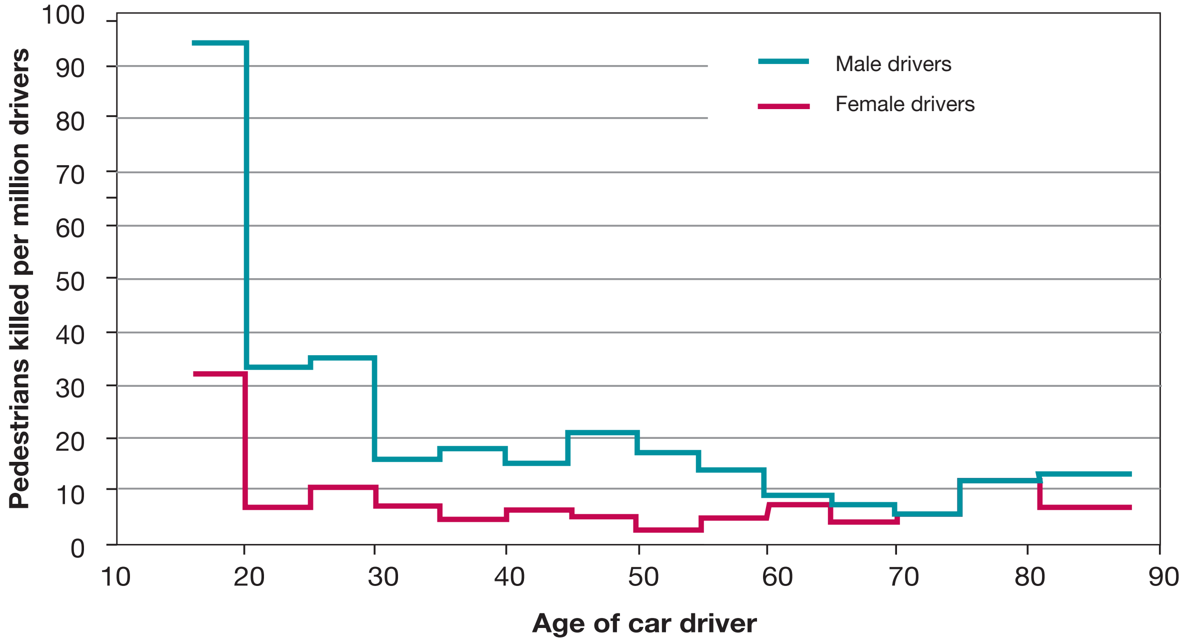
Similar results have been obtained for USA (Hakamies-Blomqvist, 2004). These showed that in USA in 1997, older drivers produced only a small proportion of all crashes leading to deaths of pedestrians (Figure 2.7).

Figure 2.6a Number of pedestrians killed by car drivers of different ages - Britain 2005



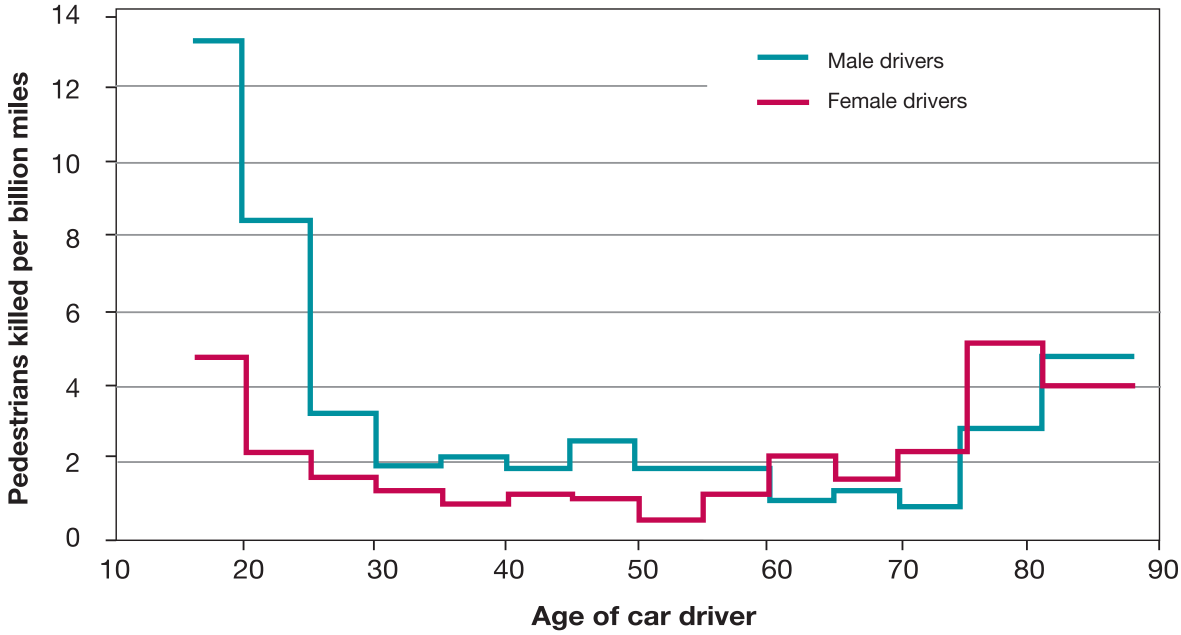
Source: DfT (2006) Road Casualties Great Britain 2005, special tabulation

Figure 2.6b Risk of a pedestrian being killed by a car driver - Britain 2005



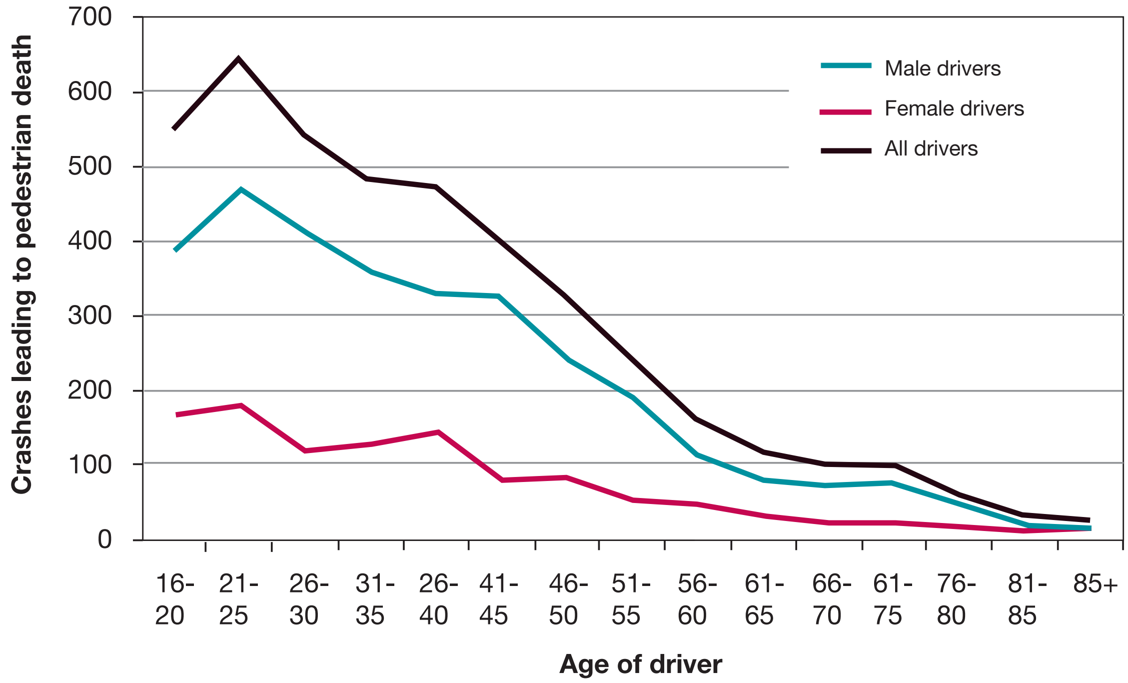
Source: DfT (2006) Road Casualties Great Britain 2005, special tabulation

Figure 2.6c Risk of a pedestrian being killed per mile driven - Britain 2005



Source: DfT (2006) Road Casualties Great Britain 2005, special tabulation

Figure 2.7 Single-vehicle fatal crashes leading to pedestrian fatality by driver age and gender, USA 1997



Source: Hakamies-Blomqvist (2004) Safety of Older Persons in Traffic, pp 22-35 in 'Transportation in an Aging Society - a decade of experience', Transportation Research Board Conference Proceeding No 27, Washington DC.

2.4 Risk per journey

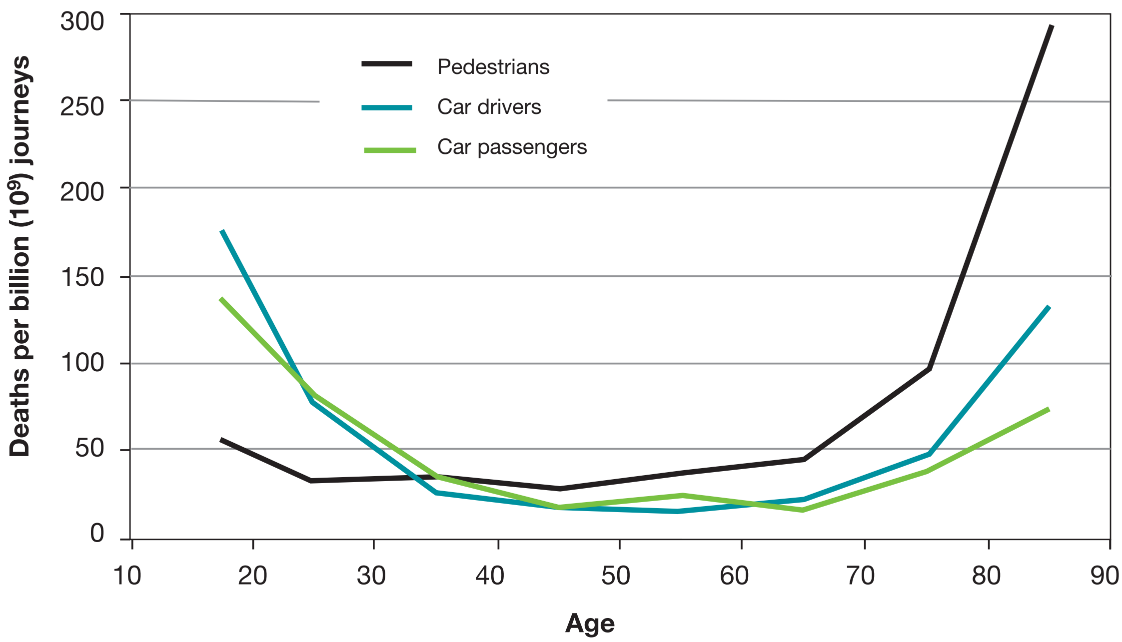
Any policies that cause people to change from making journeys as car drivers to making them by other means, such as on foot, should assess the relative risk per journey. Figure 2.8a shows the risk of being killed per journey as a car driver, as a car passenger and as a pedestrian in Britain in 2008. For people aged 60 and over, the risk as a pedestrian is much higher than as a car occupant.

Figures 2.8b shows similar rates per journey for pedestrians and car drivers killed and seriously injured in 2008, in this case separately for men and women. The risk as a pedestrian is higher than that as a car driver for people aged 70 and over. For older pedestrians in 2006, the risk per journey was similar for men and women. In 2008, women aged 80 and over had a higher pedestrian casualty rate than men. Older female car drivers have a higher risk than men for ages of 60 and over.

For policies to reduce casualties to be effective, it is necessary to understand the reality of road safety issues for elderly people. The number of elderly people is increasing, and of older car drivers even more so. Road safety policies should reflect the issues that are important, and not the misperceptions that are unfortunately all too prevalent.

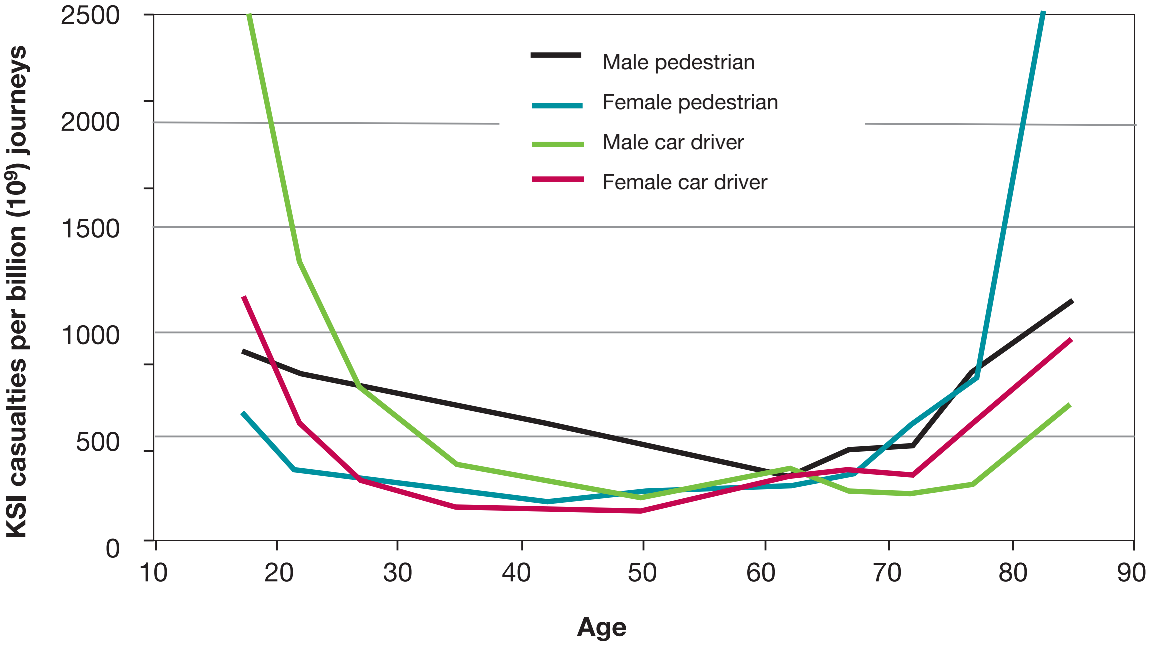
Independent mobility is very important to older people, and to them may be worth the higher risk of injury as a result of greater fragility.

Figure 2.8a Fatality rates per journey for pedestrians, car drivers and car passengers - Britain 2008



Source: DfT (2009) Road Casualties Great Britain 2008

Figure 2.8b Rates per journey for casualties killed and seriously injured (KSI) as pedestrians and car drivers - men and women - Britain 2008



Source: DfT (2009) Road Casualties Great Britain 2008

3. Safety of male and female drivers

For all age groups, fewer females than males are injured in road accidents. In Britain since 1990, male road accident deaths have outnumbered female deaths by two to one, and for casualties of all severities, males outnumber females by about 40% (Department for Transport, annual (a) date). In the USA, the ratio of male to female deaths is rather more than two to one, but slightly more females than males are injured in traffic accidents (NHTSA, 2009). In Sweden, three times as many men as women were killed in traffic accidents in 2006 (SIKA, 2007b).

3.1 Casualty rates for car drivers

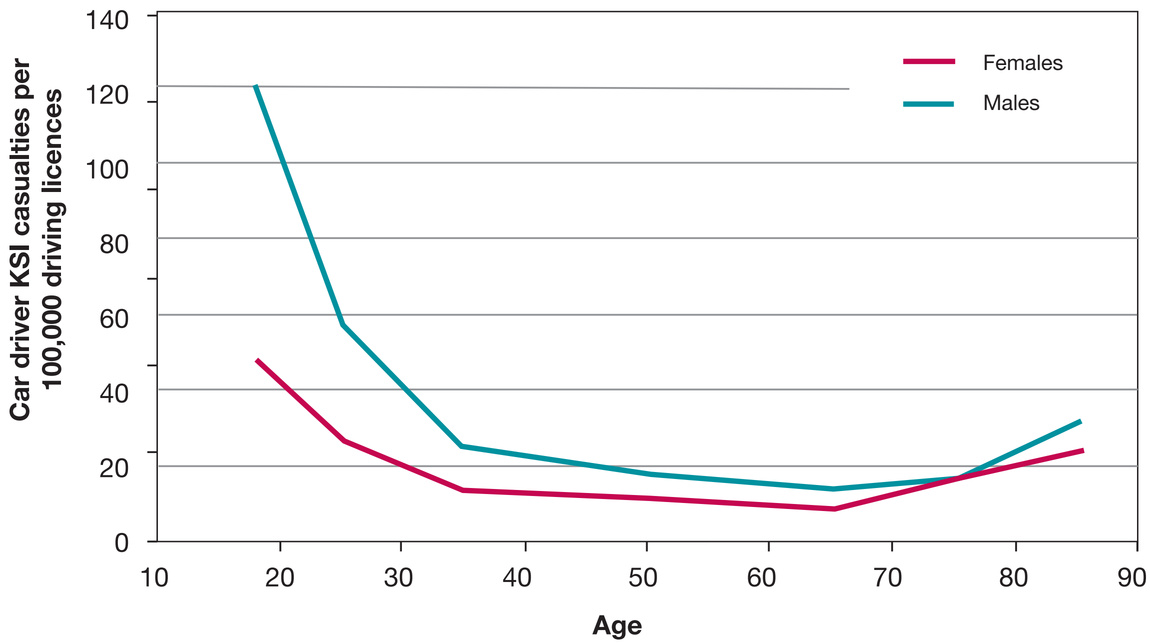
It is well known that for car drivers the fatality rate per driving licence increases with age after about 50 or 60.

Much of this increase is caused by the greater fragility of people as they age. In Britain, of car occupants injured in traffic accidents, 0.6% of those aged 30 to 49 die from their injuries, compared with 2.0% of those aged 70 to 79 and 4.5% of those aged 80 and over.

Published road safety information for Britain only gives data covering road user type, gender and age for casualties killed and seriously injured (KSI), not for fatalities or for casualties of all severities. The remainder of this section analyses KSI casualty rates for car drivers by age and gender.

Figure 3.1 shows the car driver casualty rates per licence for male and female casualties killed and seriously injured in 2008. It will be seen that for all driver ages, the casualty rate for male drivers is higher than for female drivers. However, the difference is much greater for younger drivers. By the age of 60, the rates for men and women are similar, and in some previous years the rate for older women has been higher than for older men.

Figure 3.1 Car driver KSI casualty rates per licence for male and female drivers - Britain 2008



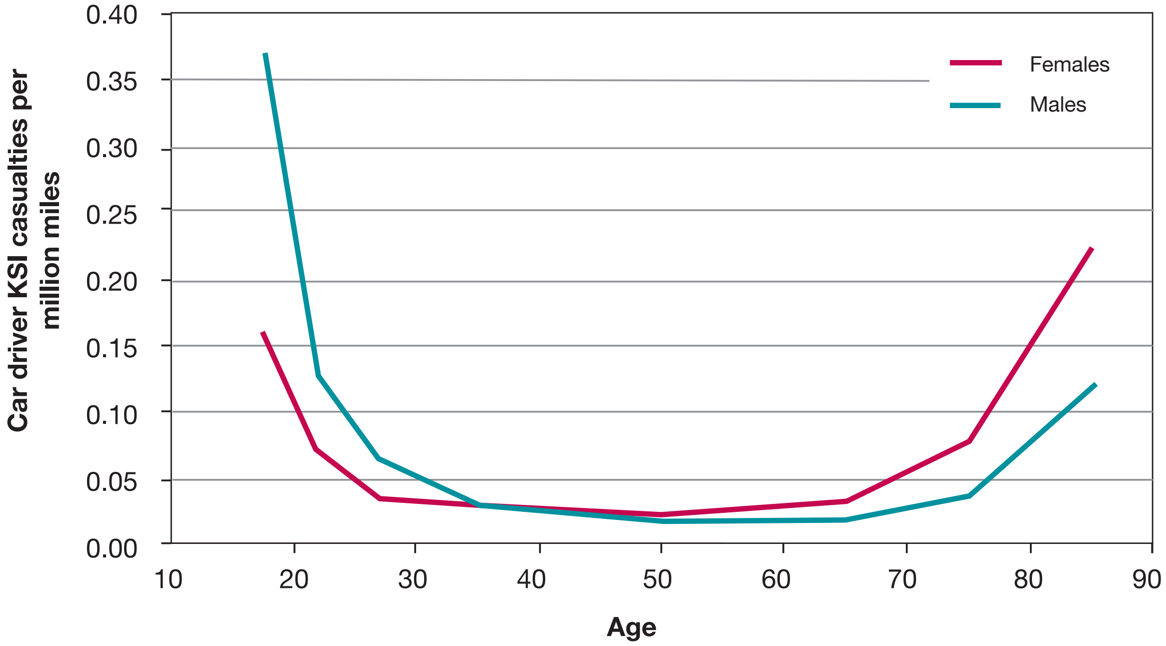
Source: DfT (2009) Road Casualties Great Britain 2008

Female car drivers drive fewer miles per year than male drivers. When the casualty rate per mile driven is calculated, women have a higher rate than men for ages over 40, although the difference does not become substantial until the age of 60 (Figure 3.2). For women, the casualty rate is lowest for ages 40 to 59, while for men it is lowest for ages 40 to 69.

There is research evidence from Britain that "males at fault were much more likely to commit deliberate risk-taking types of accident than females … For female drivers, a far greater proportion of their speed-related collisions involved ignorance of the correct speed than for males. Where females were involved in deliberate risk-taking, they were more likely to be travelling too fast for the conditions rather than above the speed limit" (Clarke *et al*, 2007).

The changes in casualty rates with age are consistent with both male and female drivers becoming safer as they become more experienced, with the difference in rates reducing for older drivers because male drivers become less reckless as they age. If this is what is happening, there could be benefit in providing refresher training for older drivers, to address problems of poor judgment of driving conditions.

Figure 3.2 Car driver KSI casualty rates per mile driven for male and female drivers - Britain 2008



Source: DfT (2009) Road Casualties Great Britain 2008

3.2 Trends in car driver casualty rates

Casualty rates per driver licence have been reducing for both male and female car drivers and for all age groups. Figure 3.3 shows the rates for male and female drivers for a number of age groups. As would be expected from the previous section, the difference in rates between male and female drivers is greatest for the youngest drivers. The casualty rate is lowest for the age group 60 to 69, which is shown in both figures.

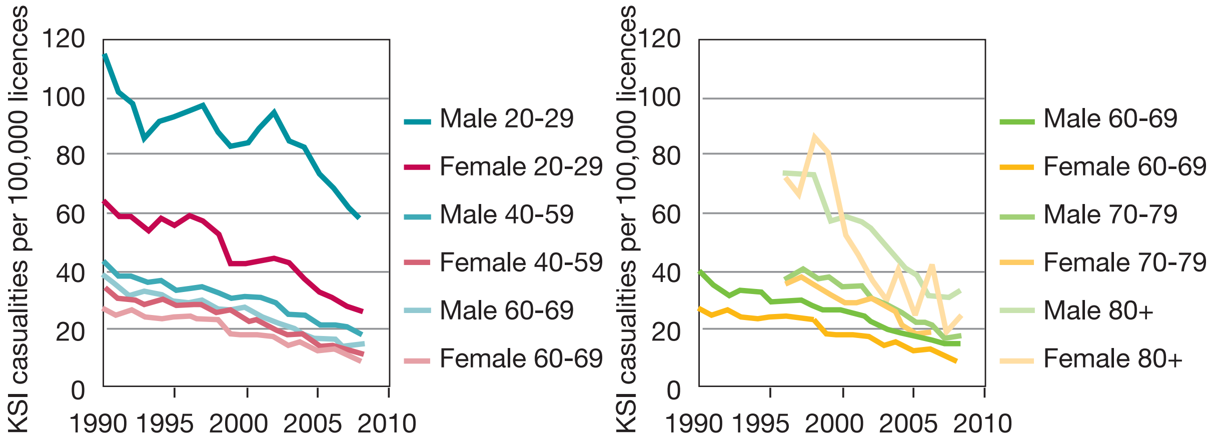
In general the rates for female drivers are lower than those for male drivers. Exceptions are 2003, when female drivers aged 70 to 79 had a higher rate than male drivers, and 1998 and 1999, when female drivers aged 80 and over had a higher rate than male drivers.

For drivers aged 80 and over, the casualty rate reduced by 60% between 1997 and 2007, while for the younger age groups the reduction was about 50%. The casualty rates per mile driven reduced more for women than men, and more for older drivers than for middle-aged drivers. This is what would be expected if women drive fewer miles than men at any age and if older women are increasing the miles they drive at a higher rate than men and younger women.

3.3 Risks to other road users

The risks of death or serious injury per journey as a car driver and as a pedestrian have been shown in section 2.4 above. The KSI casualty rates per journey for females and males in 2008 were shown in Figure 2.8b. For both men and women, the rates for pedestrian

Figure 3.3 Trends in car driver KSI casualty rates per licence for male and female car drivers in Britain



Source: DfT (Annual) Road Casualties Great Britain

casualties are higher than for car driver casualties for ages over sixty-five. Male and female pedestrians have similar casualty rates per journey for ages between 60 and 80, and the increase in casualties per journey with increasing age is clear.

3.4 Risks per journey

The risks of death or serious injury per journey as a car driver and as a pedestrian have been shown in section 2.4 above. The KSI casualty rates per journey for females and males in 2008 were shown in Figure 2.8b. For both men and women, the rates for pedestrian casualties are higher than for car driver casualties for ages over 65. Male and female pedestrians have similar casualty rates per journey for ages between 60 and 80, and the increase in casualties per journey with increasing age is clear.

Female car drivers have a lower casualty rate per journey than males for ages up to 60, but for ages over 65 have a higher casualty rate with increasing age, with the gap increasing with age. The smaller increase with age in the casualty rates for car drivers than pedestrians may reflect the greater protection in accidents that car drivers experience than pedestrians.

4. A review of literature on driving licence renewal and the safety of older car drivers

4.1 Risk of accident involvement

Studies of the effect of licence renewal procedures on the safety of older drivers date back to at least 1986. This section reviews the more significant studies, most of which suggest that more stringent tests for licence renewal by older drivers do not improve road safety, but may well reduce licence holding and mobility. Langford (2004) provides a more comprehensive review.

In Australia, Torpey (1986) evaluated the effectiveness of licensing systems by comparing older driver (75+ years) casualty crash rates in Australian jurisdictions. Victoria is the only jurisdiction without age-based re-licensing assessments. The crash rate per population in Victoria was similar to those in two other administrations, and lower than in the remaining three. Victoria had the lowest older driver crash rate per number of licences issued.

Langford *et al* (2004) compared crash rates of drivers in Melbourne, where there is no mandatory assessment of older drivers applying to renew their driving licence, and Sydney, where there is regular assessment from 80 years onward. In Melbourne, a medical report and/or road test for older drivers are only required when the driver is reported for a traffic violation, while in Sydney a medical report is required annually from age 80 onwards, and a road test annually from 85 onwards.

Drivers aged 80 years and older in Sydney had higher casualty crash rates than their Melbourne counterparts per licence issued (Table 4.1). A similar result per distance travelled was of borderline statistical significance. As these rates were per driver aged 80+ and per mile driven by those aged 80+, any population differences between the two states should not have biased the results.

In this study, uncertainties of comparisons were increased by the rather small number of respondents in the target age-ranges. Despite this qualification, it can be inferred that mandatory licence re-testing schemes of the type studied have no demonstrable road safety benefits.

In USA, Levy *et al* (1995) assessed the relationship between US state driver's licence renewal policies and fatal crashes involving drivers aged 70 years or older, for 1985 to 1989. The analysis controlled for differences among states, other than their renewal policies, likely

Table 4.1 Casualty crash involvement rates for drivers aged 80+ in Sydney relative to Melbourne

Relative crash rate	95% confidence interval Lower	95% confidence interval Upper	P-value
Per 80+ population	0.88	1.12	0.90
Per 80+ licence holders	1.02	1.29	0.02
Per distance by 80+ drivers	0.99	1.25	0.07
Per time driven by 80+ drivers	1.06	1.34	0.03

Source: Langford *et al* (2004) Effectiveness of mandatory licence testing for older drivers in reducing crash risk among urban older Australian drivers. *Traffic Injury Prevention 5 (4)*, pp. 326-335.

to influence senior motor vehicle crashes. It was found that state-mandated tests of visual acuity, adjusted for licence renewal period, were associated with lower fatal crash risk for senior drivers (relative risk, 0.93; 95% confidence interval, 0.89 to 0.97). Knowledge tests, when added to vision tests and applied only to seniors, provided a non-significant reduction in the senior fatal crash risk (relative risk, 0.91; 95% confidence interval, 0.79 to 1.05).

Loughran *et al* (2007), in a RAND Occasional Paper 'Regulating Older Drivers - are new policies needed?', used US FARS (Fatal Accident Reporting System, US DOT) data and compared the numbers of three classes of crashes:

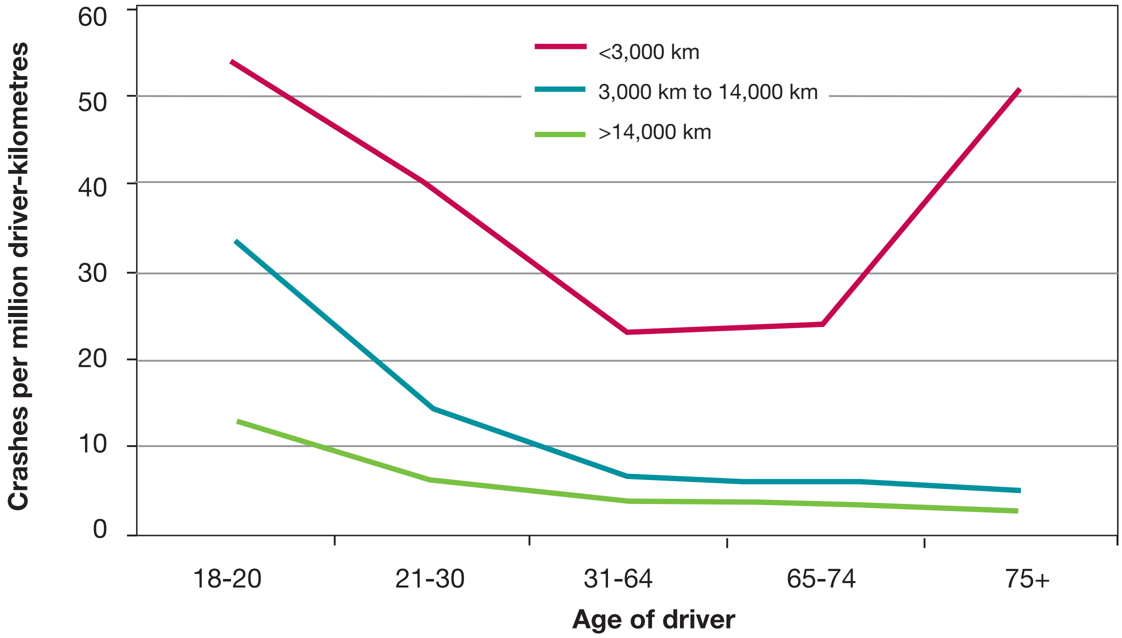
- Older drivers colliding with older drivers;
- Non-elderly adult drivers colliding with adult drivers; and
- Older drivers colliding with adult drivers.

When corrected for the extra fragility of older drivers, this enables the accident risk of the different groups to be estimated. The most important finding of this study is that older drivers are not much riskier than adult drivers (about 16% likelier to cause a crash) and far less risky than young adult drivers (188% more likely than adult drivers to cause a crash). Older drivers, who represented 15% of licensed drivers, caused 7% of all two-car accidents (both fatal and non-fatal). Loughran *et al* concluded that it is unclear from this evidence that licensing policies should target older drivers any more than they target adult drivers.

In Europe, Hakamies-Blomqvist *et al* (1996) compared the medical screening of older drivers and the traffic safety of older drivers in Finland and Sweden. Swedish and Finnish accident, licensing, and population data for the year 1990 were provided by the local authorities responsible for tabulating this data. The age-related variation in private car accident and private car fatality trends was similar in both countries. Fatalities among unprotected road users (i.e., pedestrians, cyclists, and moped riders) increased more sharply with age among the Finnish population than the Swedish population. The study found no safety-related reasons to implement age-related medical screening of older drivers of the kind practiced in Finland. On the contrary, by producing a modal shift toward walking and cycling, more risky modes of travelling, this screening may indirectly lead to higher fatality rates among older road users.

The consistent failure of evaluation studies to link stringent older driver licensing procedures with safety benefits may perhaps be due to most older drivers' intrinsic fitness to drive. For example, Langford *et al* (2006) reported a study that used Dutch survey data from a large sample to confirm previous findings on crash involvement and annual miles driven by older car drivers. Most drivers aged 75 years and above were safer than all other drivers. Only older drivers who drove less than 3000 km per year showed elevated crash rates per kilometre. The principal result is shown in Figure 4.1.

Figure 4.1 Accident involvement (all severities) per million driver kilometres



Source: Langford *et al* (2006) Older drivers do not have a high crash risk—A replication of low mileage bias. *Accident Analysis & Prevention* Volume 38, Issue 3 , May 2006, pp 574-578.

This study concluded that overall, older drivers are not a high-risk group. There are no grounds for testing the driving fitness for an age group, most of whose members are at least as safe as drivers of other ages. Attempts to identify high-risk drivers should focus upon those drivers giving some evidence of being at risk.

From these and other studies, it is clear that in Australia and Europe, the accident rate for older drivers increases only slightly with increasing age, and that aged-based screening of older drivers does not improve road safety, but does reduce mobility by reducing the retention of driving licences. This does not mean that there are not some older drivers who should stop driving, but population screening is not an effective way to identify them.

4.2 Licence renewal procedures in Europe

Licensing of motor vehicle drivers is handled at a national level in Europe. A European driving licence system is being developed by the European Commission, though this will still be administered at a national level.

The procedures for renewing the licences of older car drivers vary greatly between countries, and the European Commission (2002) has published details of driving licence validity and the requirements for periodic medical examinations in European countries in 2002 (Table 4.2).

Table 4.2 Validity of car driving licences and periodicity of medical examinations - European Union 2002

Country	Licence validity	Medical examinations
Belgium	Unlimited validity	
Denmark	Valid up to holder's 70th birthday Valid for 4 years when holder is 71, For three years when he is 72, and for two years when he is 73-79. For one year when he is older than 80.	
Germany	Unlimited validity	
Greece	Valid up to holder's 65th birthday, thereafter for three years.	
Spain	Valid for 10 years up to holder's 45th birthday For five years when holder is 45-70 For two years when holder is older than 70.	
France	Unlimited validity	
Ireland	Valid for three-10 years (optional) up to holder's 60th birthday For three years when holder is 60-69 For one to three years (determined by medical check) when holder is older than 70.	
Italy	Valid for 10 years up to holder's 50th birthday For five years when holder is 51-70 For three years when holder is older than 70.	
Netherlands	For 10 years up to holders 60th birthday Up to the holder's 70th birthday, when he is 60-65 For five years when the holder is older than 64.	At the age of 70 At five yearly intervals thereafter.
Austria	Unlimited validity	
Portugal	Valid up to the holder's 65th birthday For five years when holder is older than 65 For two years when holder is older than 70.	
Finland	Initial validity of two years; after this period, valid up to holder's 70th birthday For five years when the holder is older than 70.	At the age of 45, 60, 70 At five yearly intervals thereafter.
Sweden	For ten years	At the age of 70
Norway	Valid until holder's 100th birthday	
United Kingdom	Valid up to holder's 70th birthday For three years when the holder is older than 70.	At age 70 (self-declaration) At three yearly intervals thereafter (self-declaration)

Source: Commission Interpretive Communication on Community Driver Licensing (2002/C 77/03), section B.1. *Official Journal of the European Communities* 28.3.2002.

At present four countries (Belgium, France, Germany and Austria), issue licences of unlimited validity. Six further countries issue licences to ages of 65, 70 or 100 years. Five countries issue licences for 10 years to some age between 45 and 70. One country requires a medical examination at 45, 60, 70 and then five-yearly intervals; at least two others require medical examinations from age 70, and one requires a self-declaration of medical fitness to drive from age 70. In all countries, the renewal of licences for commercial drivers is more stringent. However, the EU Council of Ministers has reached a political agreement on a European Commission proposal regarding the introduction of a common European driving licence. The new driving licence is due to come into effect by 2012 although member states will have until 2032 to replace all existing driving licences. Validity periods will be harmonised for all new licences issued after the date of application of this directive: 10 years validity for driving licences for motorcycles and cars (with a possibility for member states to raise the validity period up to 15 years).

In practice, the procedures listed in Table 4.2 are not always fully implemented. For example, although Sweden specifies that a medical examination is required at age 70, the licensing authority also provides a detailed self-completion medical questionnaire. It is not clear how often this is used in place of a medical examination.

Accidents are very rare events. This has two implications. The first is that it is not practical to conduct studies of the effect of safety measures on accident rates - there simply are not enough accidents for changes due to safety measures to be detectable. The second is that a large number of marginal drivers have to be stopped driving, with all the mobility consequences, to save one accident.

5. A case study of seven European countries

The four Scandinavian countries (Denmark, Finland, Norway and Sweden), the Netherlands, France and the United Kingdom / Great Britain, provide the opportunity to observe the effect of the licence renewal procedure for older drivers on licence retention, mobility and road safety.

5.1 Licence renewal procedures

The requirements for the seven countries of this case study can be determined from Table 4.2. France issues car driving licences for life, and Norway to age 100. Denmark, Sweden, Finland and United Kingdom issue licences to age 70, then for various periods thereafter. The Netherlands issue licences for 10 year periods to age 60 and five year periods from 65. Medical examinations are required at 70 in Sweden, at 70 and five year intervals thereafter in the Netherlands, and at age 45, 60, 70 and five year intervals thereafter in Finland.

Denmark is quoted in OECD (2001) as requiring a medical examination for licence renewal, although this is not mentioned in Table 4.2. The current situation is not known. Although Sweden formally requires a medical examination for licence renewal from age 70, in practice a self-completed medical questionnaire is usually accepted. Similarly, the certificate of medical examination required in the Netherlands must not be provided by the driver's family doctor, and is said to be relatively easy to obtain.

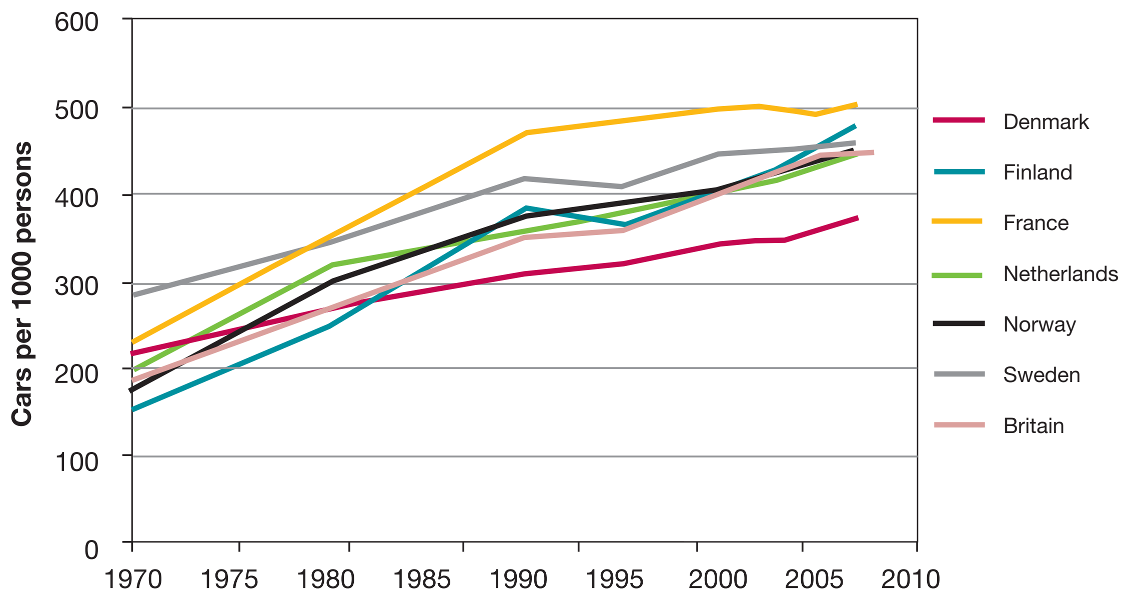
Thus the seven countries can be grouped into three categories:

- France, the United Kingdom, the Netherlands and Sweden, which have relatively relaxed re-licensing arrangements in practice, even if the formal procedure is more stringent;
- Finland, and possibly Denmark, which have stringent medical assessment for licence renewal; and
- Norway, which has a procedure that appears to be relaxed but which has large reductions in the percentage of people holding driving licences at 65 and 70 years old.

5.2 Car ownership and overall road safety

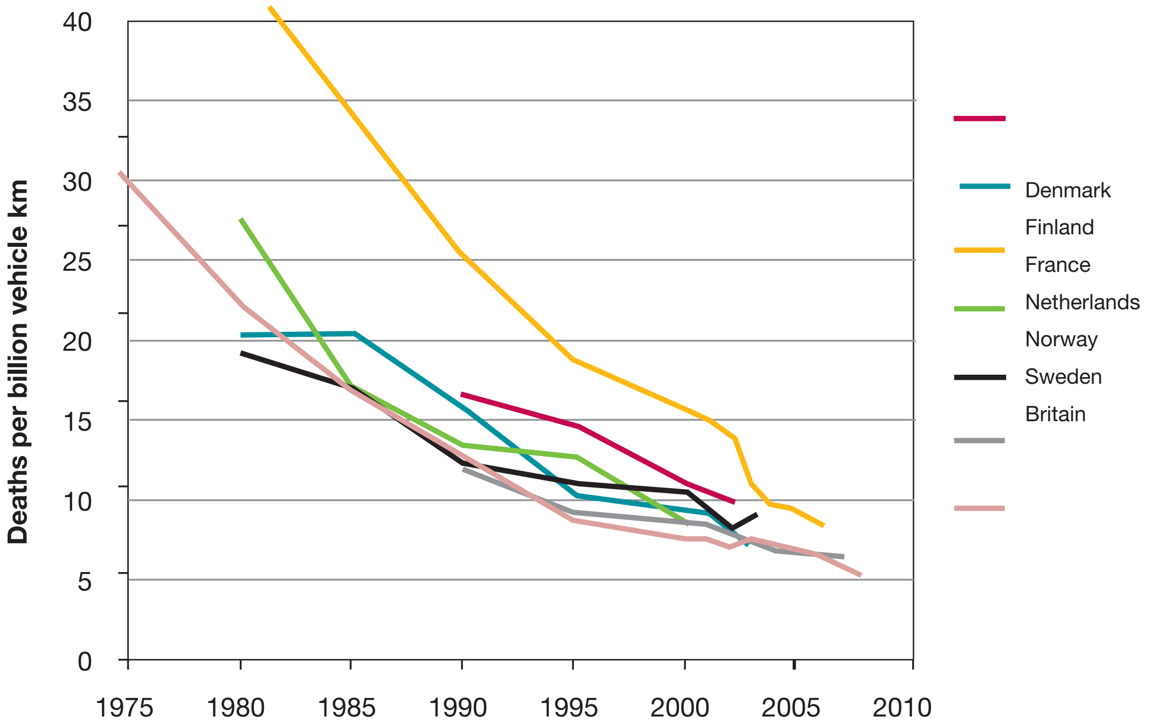
All seven countries have similar levels of car ownership (Figure 5.1). Denmark has the lowest car ownership because of deliberate policies that raise the cost of car ownership and use.

Figure 5.1 Car ownership in the seven countries for the case study



Source: European Commission (2009) and Department for Transport (annual)(c)

Figure 5.2 Road accident fatality rate per unit traffic, all road users



Source: UNECE (annual) and Transport Statistics Great Britain (Department for Transport, annual)

Except for France, the seven countries have similar road safety in terms of fatality rate per population and per unit traffic for all road users, and since the year 2000, France has reduced its fatality rates to near those of the other six countries (Figure 5.2).

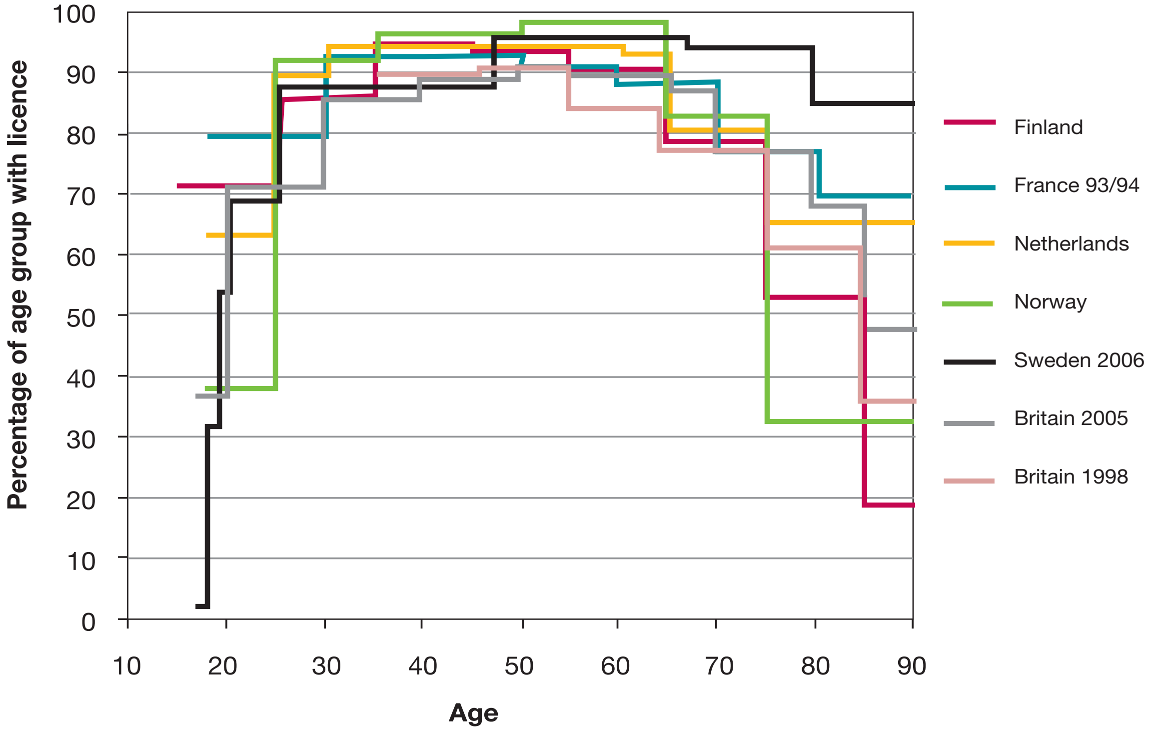
5.3 Licence holding

An OECD study on transport and ageing obtained information on driving licence holding in a number of European countries (OECD, 2001) (Figure 5.3). The data for Britain and Sweden has been updated using national statistics. Licence holding declines more in older age in Finland and Norway than in Sweden, France, the Netherlands and, to some extent, Britain. This reflects the ease of licence renewal by older drivers, and may indicate the deterrent effect on older drivers of excessively stringent re-licensing procedures. The data for Sweden is from Statistics Sweden and is for 2006. Licence holding in Sweden for older men and women is the highest of the seven countries.

5.4 The safety of older drivers

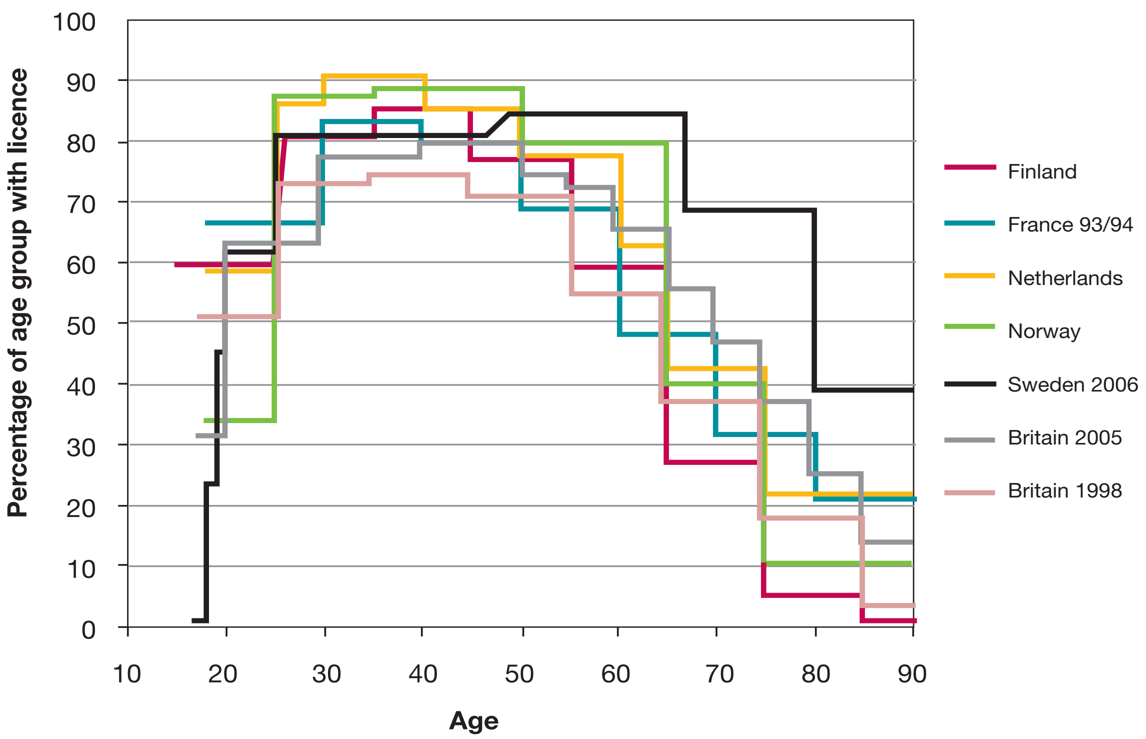
Figure 5.4 shows that the fatality rates per population for middle aged and elderly drivers are generally similar, though somewhat higher in Scandinavia and France than in the Netherlands and Britain (note - these are fatalities per person of the appropriate age, not per driver). In all four Scandinavian countries the fatality rates for drivers aged 65+ are higher than for drivers aged 25 - 64, with the difference being greatest in Denmark. The

Figure 5.3a Car driving licence holding, 1998 - men



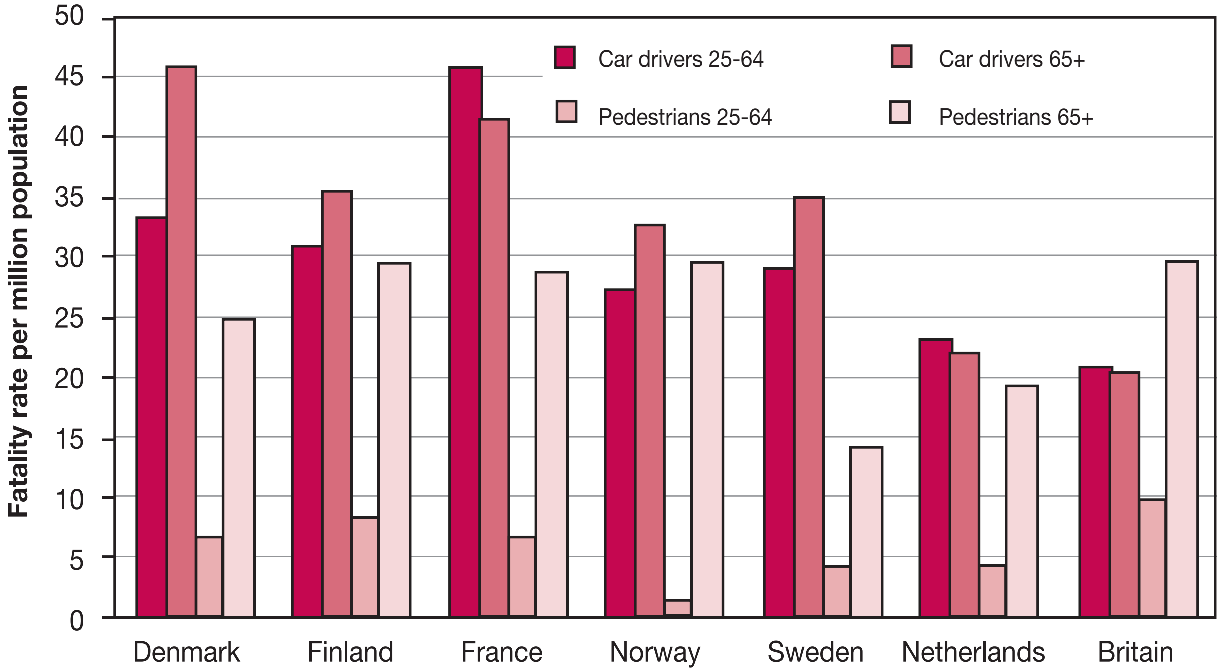
Source: OECD (2001) Ageing and transport - mobility needs and safety issues. OECD, Paris, updated

Figure 5.3b Car driving licence holding, 1998 - women



Source: OECD (2001) Ageing and transport - mobility needs and safety issues. OECD, Paris, updated

Figure 5.4 Fatality rates per population for middle aged and older car drivers and pedestrians 2003



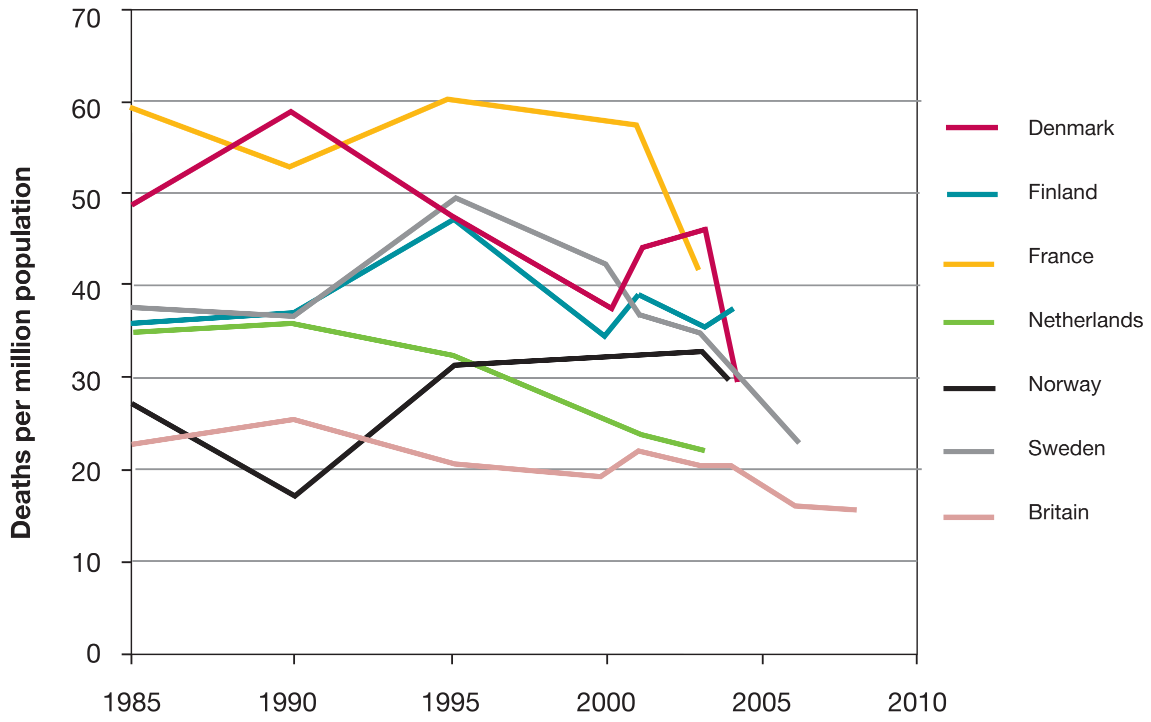
Source: UNECE (annual)

opposite is the case in France, the Netherlands and Britain, which all have higher levels of licence holding by older drivers, and more relaxed renewal procedures. There is no indication of an effect on safety of the reduced licence holding in Finland or Norway, nor of any deleterious effect of the relaxed renewal procedure in France, Sweden, the Netherlands and Britain.

The safety of older pedestrians is best in the Netherlands and Sweden, and of pedestrians aged 25 - 64 in the Netherlands, Norway and Sweden. The safety of older pedestrians is worst in Finland, France, Norway and Britain. It is notable that Finland and Norway have low levels of driving licences among older people. Hakemies-Blomqvist *et al* (1996) has suggested the high rate for pedestrian fatalities in Finland could be a consequence of the high proportion of older people who lose or give up their driving licence. However, Britain and France have high levels of driving licences, but still have high fatality rates for older pedestrians.

Figure 5.5 shows the trends in fatality rates per population for car drivers aged 65+. For this age group, France, the Netherlands, Sweden and Britain have the highest level of car driving licence holding (the higher level in Norway for the group 65 - 74 is more than compensated by the lower level for ages over 75). Yet Britain and the Netherlands have the lowest fatality rates for car drivers aged 65+, demonstrating that allowing a higher proportion of older drivers to retain their licences does not have an adverse effect on road

Figure 5.5 Fatality rate per population for car drivers aged 65+



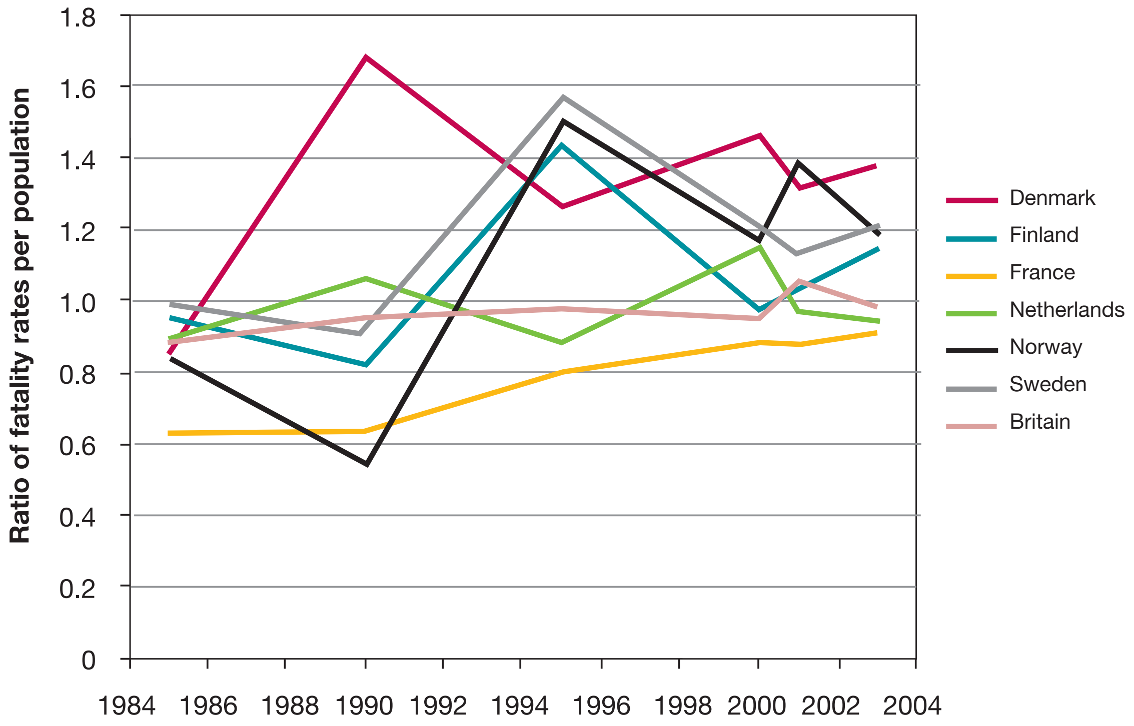
Source: UNECE (annual)

safety. France had a relatively high fatality rate, but this reflected the very high fatality rate for younger drivers, and has reduced as general road safety in France has improved since the year 2000. The unlimited validity of driving licences in France has no obvious adverse effect. Finland and Sweden have identical fatality rates for older drivers, despite very different licence renewal procedures and the much higher proportion of older people who hold driving licences in Sweden. This difference in licence holding suggests that the fatality rate per licensed older driver is much lower in Sweden than Finland.

One way to indicate whether older car drivers are more or less safe than middle aged drivers is to plot the ratio of the fatality rate for drivers aged 65+ divided by the fatality rate for drivers aged 25 - 64. The higher the relative accident rate for older drivers, the higher is this ratio. The calculation is confused by the difference in licence holding with age. The more licence holding declines after age 65, the lower the ratio will be for similar fatality rates per licensed driver, as opposed to per population.

Figure 5.6 shows this ratio for the seven countries, over the period 1985 to 2003. It is noticeable that the curves for France, the Netherlands and Britain lie at the bottom of the range for the seven countries, and all have values at or below 1.0. That for Sweden is similar to those in Norway and Finland, and that for Denmark is relatively high. Because licence holding for older drivers is higher in France, the Netherlands, Britain and Sweden

Figure 5.6 Ratio of the fatality rate per population (not per driver) for car drivers aged 65+ divided by the rate for car drivers aged 25 - 64



Source: UNECE (annual)

than for the other two for which data are available (Norway and Finland), the effect of licence holding would move the curves for France, the Netherlands, Britain and Sweden to the upper part of the range. Since three of the curves actually fall towards the bottom of the range, and that for Sweden is similar to those for Norway and Finland, and below that for Denmark, it shows that these four countries have fatality rates for older drivers that increase less with age (if they increase at all) than do the rates in Norway, Denmark and Finland.

This confirms that the four countries that have the highest level of licence holding for older car drivers also have the lowest ratio of fatality rates for older car drivers relative to the rates for middle aged car drivers.

In countries where licences are issued for life or where renewal is easy, there will be licence holders who drive very little or not at all. Langford *et al* (2006) have shown that it is the drivers who drive very little who experience an increase in accident involvement after the age of 75. There is no data on the number of people with driving licences who do not drive at all, so it is not possible to estimate the effect of these non-drivers on the apparent accident rate per licensed driver.

It appears that the relatively relaxed licence renewal procedures in France, the Netherlands, Sweden and Britain provide a good balance between maintaining the mobility of older people without compromising road safety. This is not to argue that older drivers who are 'obviously unfit' to continue driving should not be identified and should not lose their driving licence. It is suggesting that the process that detects those drivers who are 'obviously unfit' should not place such a burden on all drivers that it deters some who are fit to continue driving from doing so.

5.5 Conclusions on licensing older drivers

European countries currently practice a wide range of car driving licence renewal procedures. In a case study of France, the Netherlands, the United Kingdom and the four Scandinavian countries, the countries with the most relaxed licence renewal procedure and least demanding requirement for medical examinations (France, United Kingdom, the Netherlands and Sweden) have the highest level of driving licence holding by people aged 65+; United Kingdom and the Netherlands have the lowest fatality rate per population (not per licensed driver) for car drivers aged 65+, and Sweden the fourth lowest. France had a relatively high fatality rate in the 1990s, but this reflected the very high fatality rate for younger drivers, and has reduced as general road safety in France has improved since the year 2000.

There is no evidence that any licence renewal procedure or requirement for a medical examination has any effect on the overall road safety of people aged 65+, though undoubtedly there are individual drivers who should no longer be driving who might be detected by stringent renewal procedures.

6. Mobility

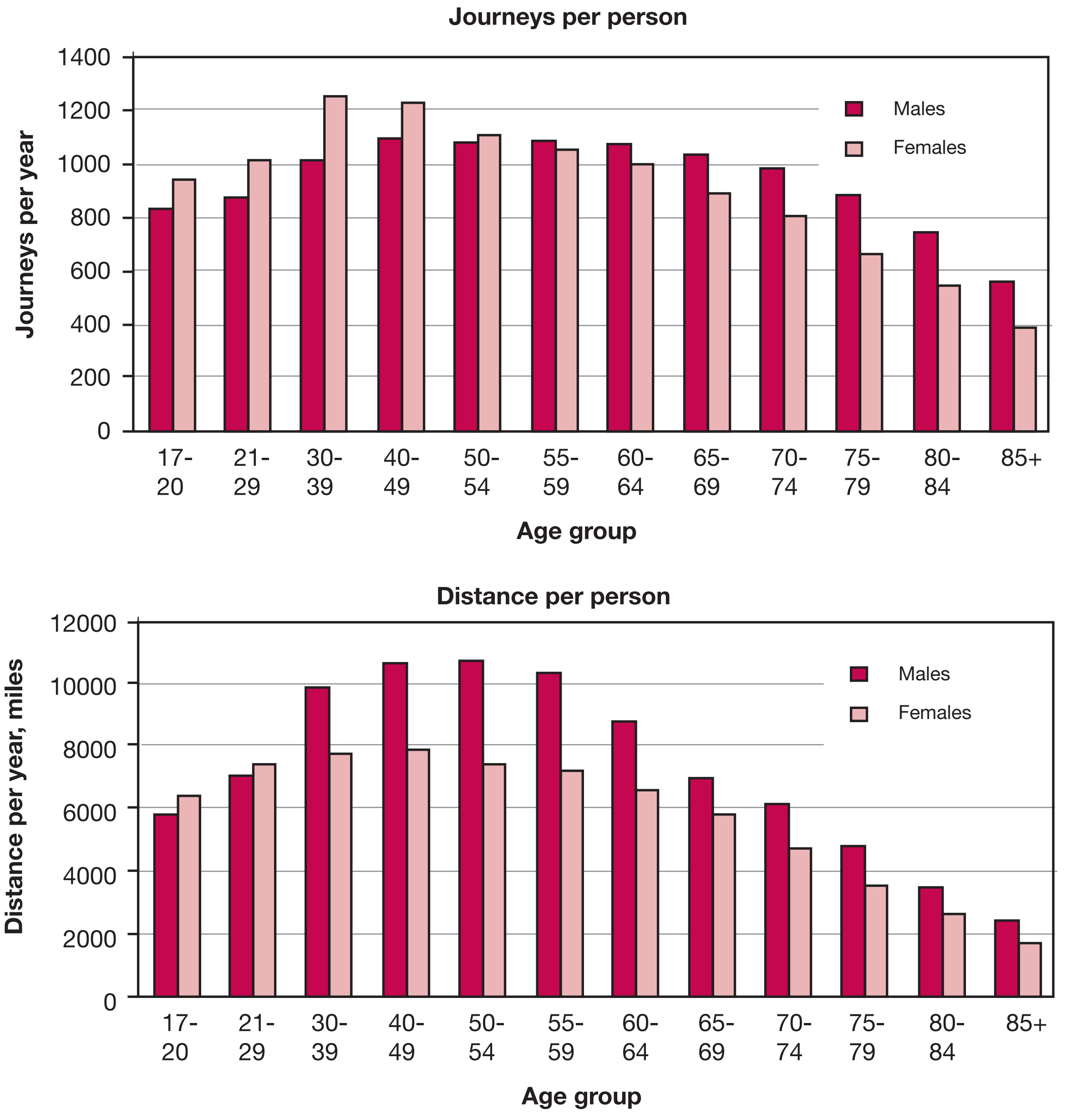
6.1 Number of journeys and distance travelled

Younger women make more journeys per day or per year than men, but older men make more journeys than women (Figure 6.1). Until 2005, at all ages, men in Britain travelled further than women. By 2006-8, women aged up to 29 travel slightly further than men. For Britain, these data come from the National Travel Survey (Department for Transport, annual (b)); for the USA, the National Household Travel Survey provides similar data (BTS, 2005); and for Sweden, RES, the National Travel Survey (SIKA, 2007a).

6.2 Purposes of travel

The purposes for which people travel vary between men and women, as well as with age (Figures 6.2). For both women and men, journeys to work and education reduce with increasing age, for women particularly after age 60 and for men particularly after age 65 (the traditional retirement ages in Britain). Women make more journeys than men to

Figure 6.1 Journeys and distance per person per year by age and gender Britain, 2006-8

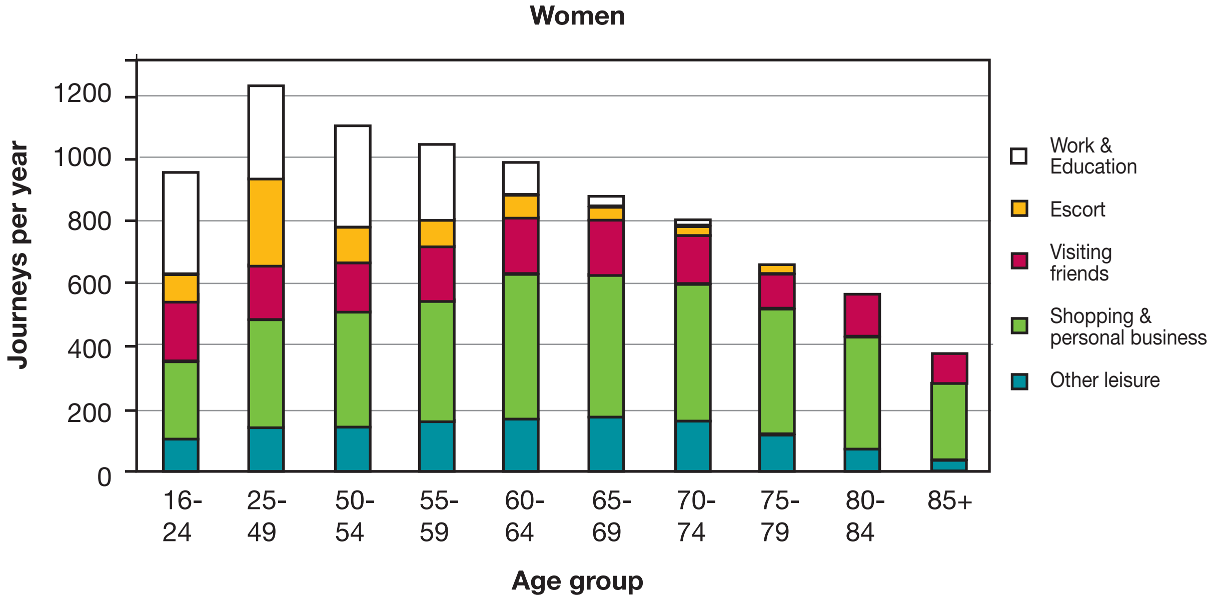


Source: DfT (Annual) National Travel Survey, special tabulation

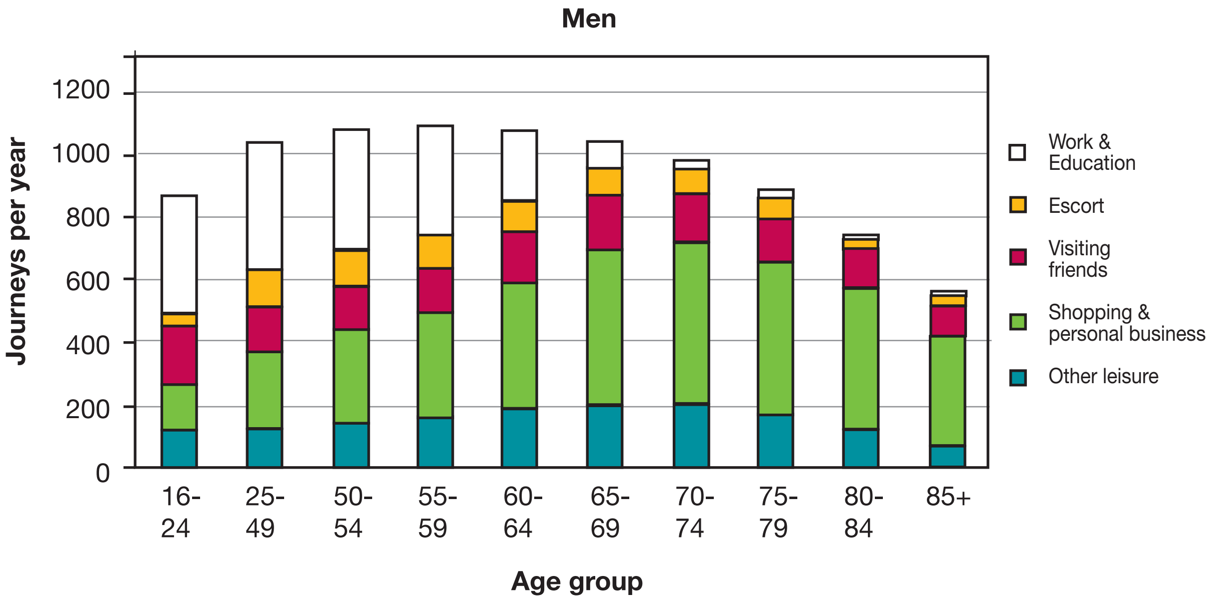
escort others. Some of these escort journeys are for school journeys, but the majority are not; only women aged 30 to 39 make more escort journeys for education than for other purposes.

Visiting friends is a significant purpose for both genders, and the number of journeys remains fairly constant to age 75 or above. For men, shopping and personal business (health care, visiting the bank and other similar activities) journeys increase after age 60

Figure 6.2 Journeys per year by age and purpose - Britain, 2006-8



Survey, special tabulation



Source: DfT (Annual) National Travel

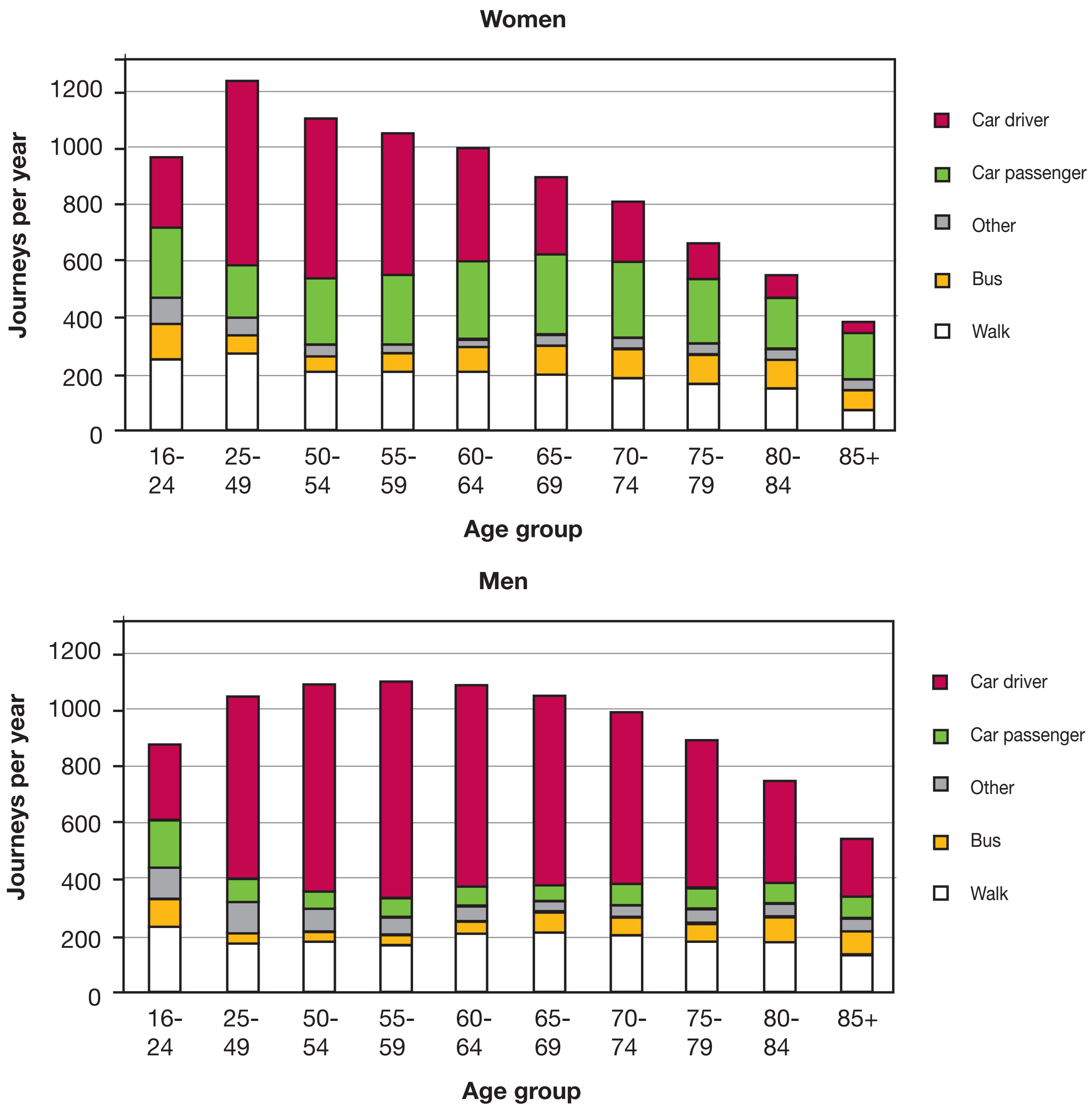
and remain high to age 80. For women the increase after age 60 is smaller and only lasts to age 70.

For both women and men there is an increase in the number of journeys for non-work activities after retirement, that lasts into the 70s for women and 80s for men. There is no indication that transport difficulties are reducing people's activities, although there are undoubtedly many older individuals whose activities are limited by transport problems. A report on the transport needs of older people (Atkins, 2001), and another on social exclusion in Britain (Social Exclusion Unit, 2003), identify transport as a significant cause of being unable to engage in some desired activities.

6.3 Mode of travel

Men make more of their journeys as car drivers, while women are more likely to travel as car passengers (Figure 6.3). Almost all the reduction in the number of journeys people

Figure 6.3 Journeys per person per year by mode - Britain, 2006-8



Source: DfT (Annual) National Travel Survey, special tabulation make over the age of 70 (for men) or 50 (for women) is a result of making fewer journeys as car drivers.

Men aged 65 to 69 increase the number of journeys they make as pedestrians, and those aged 70 to 85 increase the number of journeys by bus. Women aged 65 to 85 also increase their journeys by bus.

The tendency at all ages for men to drive cars and women to travel as car passengers appears in every country for which data are available. The USA is more car dependent than European countries, with about 90% of all journeys by car, 8% as pedestrians and 2% by public transport. Also, in the USA, the percentage of journeys by non-car modes does not increase with age above 60 years old, as it does in Britain and other European countries.

6.4 Travel by holders of car driving licences

The reduction in journeys as car drivers with increasing age is partly caused by a reducing percentage of the older population holding driving licences, and partly because those with driving licences drive less. To separate these effects, Figure 6.4 shows the number of car driver journeys per year by people with car driving licences, and the average length of those journeys.

Women with driving licences reduce the number of journeys they make as car drivers from age 50, with the number of journeys falling steadily from 730 per year at age 50 to 54, to 220 a year for ages of 85 and over. Men maintain a rate of 700 - 800 journeys a year to age 75 and reduce to 460 a year for ages of 85 and over. The average length of women's car driver journeys varies little with age, ranging between 5 and 7 miles over the whole age range. Younger men make longer journeys, typically 10 or 11 miles up to age 65, and then reduce their average journey length to about 5 miles for ages of 80 and over.

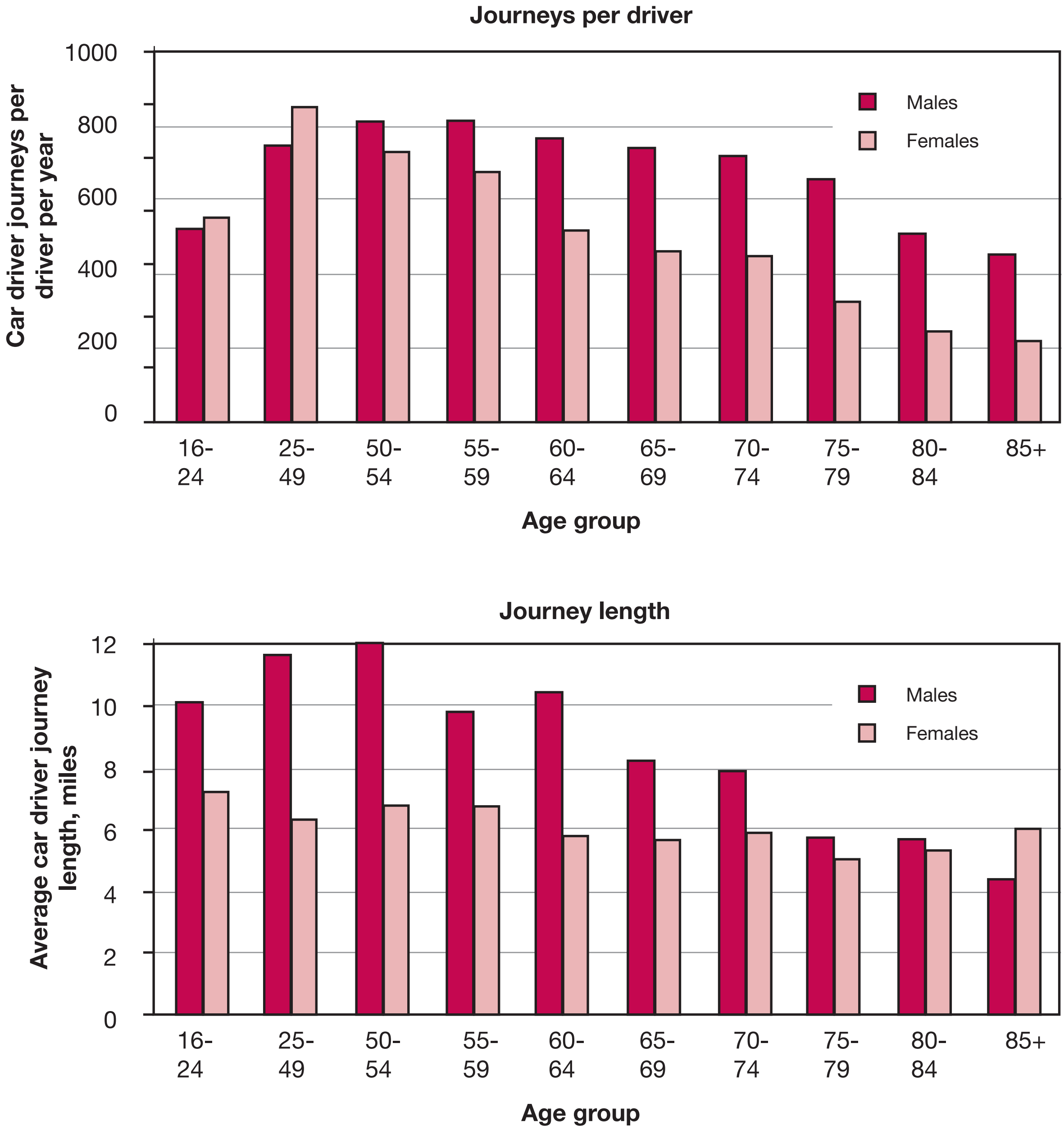
There is no research to establish whether the reduction in the number of car driver trips by older women is a result of having fewer activities to which to travel, of making more journeys as a car passenger after the retirement of her husband, or of self-regulation causing women to stop driving under more stressful conditions, such as at night. Anecdotal evidence suggests that women do avoid driving at night, on motorways and for long distances at younger ages than men.

6.5 Driving licences

In Britain, car driving licence holding by men increased rapidly in the 1970s to 1990s, but is now saturated for men up to the age of 75. It is still increasing for older men. About ninety per cent of men aged 30 to 70 hold a driving licence, and about 80% of those in their early 70s (Figure 6.5).

Licence holding by women was much lower than that of men, but is increasing. For

Figure 6.4 Car driver journeys per licensed driver and average journey length - Britain, 2006-8

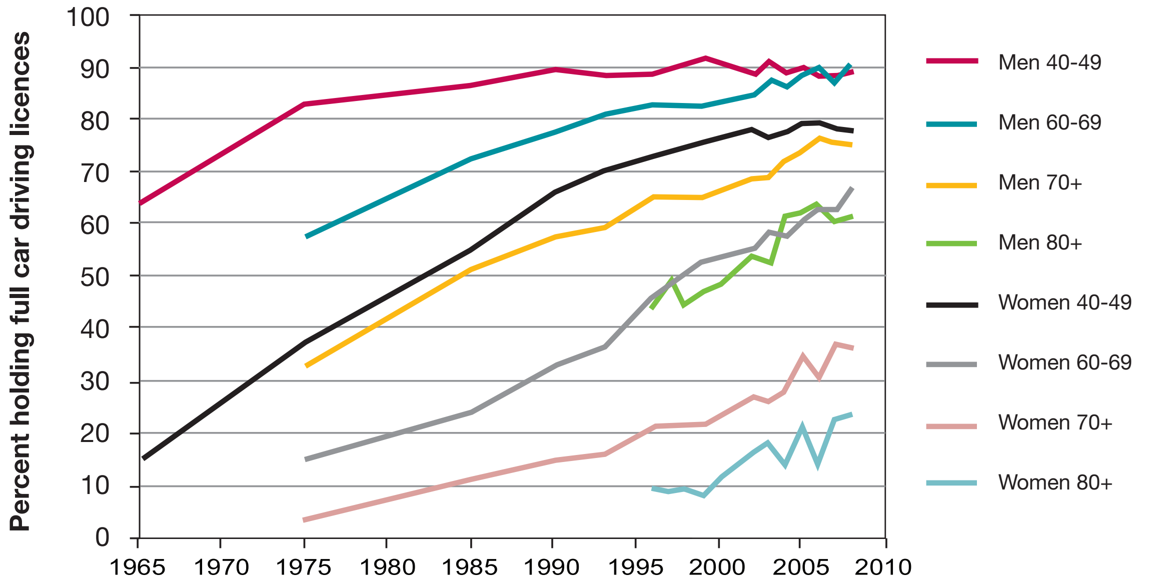


Source: DfT (Annual) National Travel Survey, special tabulation

women in their 40s in 2008, licence holding appears to have just reached saturation at around 80% of the population, but for all older age groups it is still increasing.

The increase in licence holding in older age groups occurs because most drivers obtain their licence in young or early middle age, and then retain it into older age. Thirty-seven

Figure 6.5 Percentage of men and women holding full car driving licences - Britain



Source: DfT (Annual) National Travel Survey, special tabulation

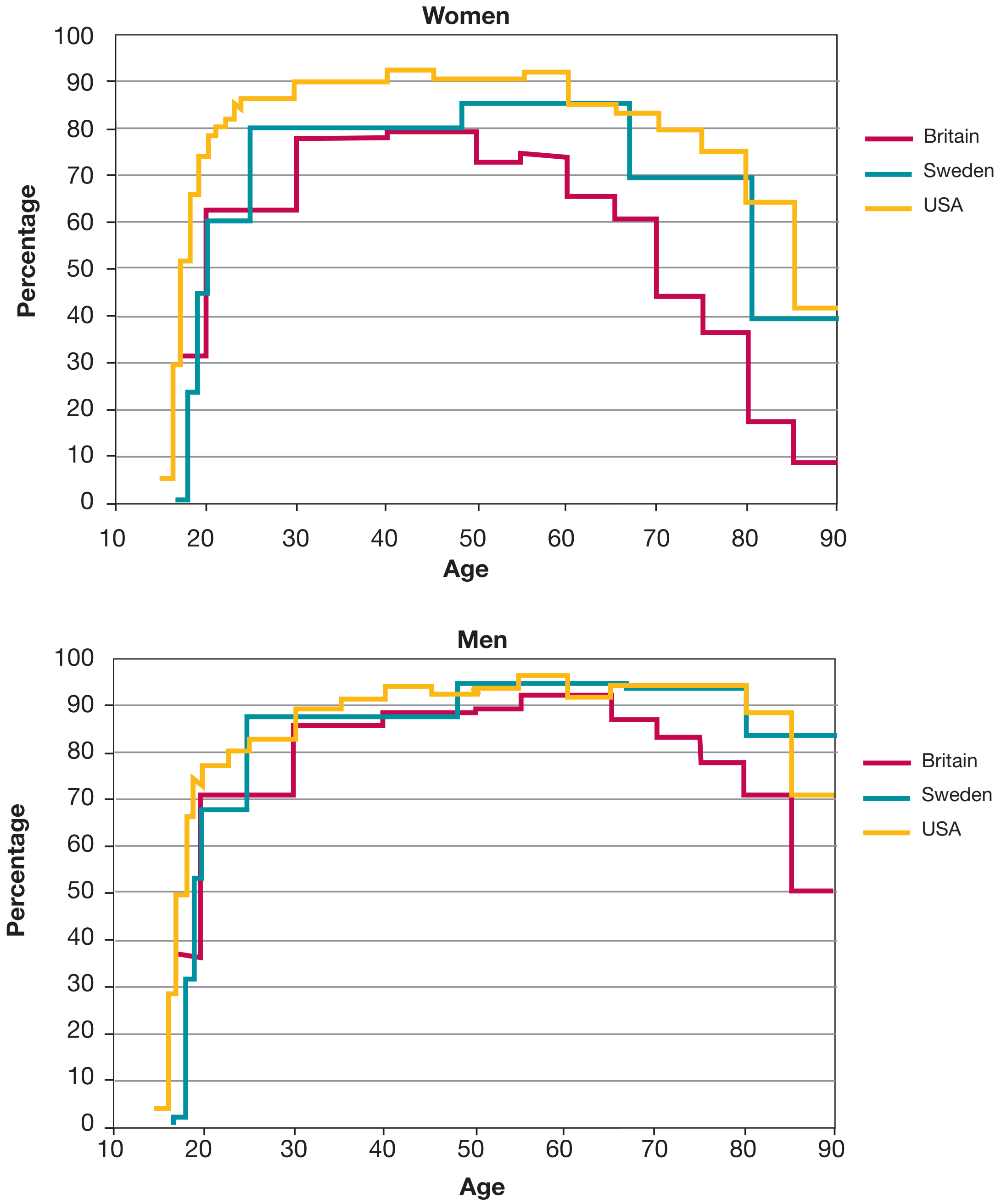
per cent of women aged 40 to 49 in 1975 held a driving licence; by 1985, 41% of this cohort held a licence; by 1995-97, with the cohort aged 60 to 69, 45%; by 2005, aged 70 to 79, 42%; and by 2008, about 40%. Men aged 70 and over have had a slightly lower percentage of licence holding than women aged 40 to 49 since 1975. Between 1975 and 2007, licence holding by both groups has increased from about 35% to about 77%.

By following the licence holding of cohorts through National Travel Surveys, it is possible to estimate the percentage of drivers who surrender licences at various ages. For men, there is clear evidence of some surrendering of licences from age 70 onwards. For the cohort of men in their 60s in 2005, licence holding is about 88% and has been steady for the previous twenty years. For those in their late 70s in 2005, licence holding is 76%, about 6% down from the 82% holding by that cohort in 1995 and 81% in 1985.

By age 85 and over it was 48% in 2005, down by as much as 18% from the 66% for 75-79s in 1995, and by 20 to 24% from the 72% holding for those aged 60-69 in 1985. Interpretation of the surrendering of licences depends on the assumption that mortality rates are the same for licence holders and non-holders. In the extreme case of all deaths occurring to non-holders, the percentage licence holding would increase with age despite no change among those already holding licences. Since non-holders are likely to be poorer or in worse health, this effect may be occurring, but its significance cannot be assessed.

For women, licence holding is always lower than for men of the same age, but there is little evidence of licences being surrendered earlier than by men. For women in their 60s in 2005, of whom about 64% hold licences, there is no evidence of a reduction in licence holding over the previous decade. For those in their mid-70s in 2005, the reduction is from about 45% nine years earlier to 42% in 2005 and 40% in 2008. For women in their mid 80s in 2005, licence holding is about 15%, compared with about 22% a decade earlier for the same cohort.

Figure 6.6 Percentages of men and women holding car driving licences in USA, Sweden and Britain in 2006



Sources: National Travel Survey, Department for Transport 2008, Special Tabulation, Highway Statistics 2006, Table DL-20, US Department of Transportation, Swedish Statistical Handbook 2008, Table 269, Statistics Sweden

Higher percentages of people in the USA and Sweden hold car driving licences than in Britain, and in Britain the percentage holding licences reduces more with age (Figure 6.6). For women, this reflects lower licence holding in the past by middle aged women. For men aged 75 and over, and for women aged 50 and over, licence holding is increasing. Licence holding in Sweden and USA is similar, though a little lower for women in Sweden.

7. Self-regulation

Older female drivers start to reduce the number of car driver journeys they make about twenty years younger than older male drivers, from age 50 for women and from age 75 for men. This reduction may indicate that women self-regulate their driving to avoid stressful conditions at younger ages than male drivers, but there is no research evidence to confirm that this is occurring. Also, following cohorts of drivers provides no evidence that women surrender driving licences at younger ages than male drivers.

Research in Britain in the 1990s (Simms, 1993; Rabbitt *et al* 1996) identified driving conditions and features of the road system that older and disabled drivers try to avoid. Table 7.1 from Simms (1993) shows the percentage of drivers aged 70 and over who try to avoid and who had changed their behaviour to avoid certain situations.

Table 7.1 Percentage of drivers who try to avoid and who have changed their behaviour to avoid certain traffic situations on local journeys - Britain

Situation	Percentage who try to avoid	Of those who try to avoid, percentage who have changed behaviour to avoid
Busy times	62	25
Multi-storey car parks	52	22
Town centres	32	26
Complicated junctions	23	16
Roundabouts	14	38
Changing lanes	14	16
One way systems	12	25
Merging into traffic flows	11	21
Right turns	9	33
Country lanes	7	10
Dual carriageways	5	23

Source: Simms (1993)

Table 7.2 Percentage of drivers who have reduced driving in specified conditions Britain

Per cent of drivers in age band

Specified condition	Drivers aged 50 to 65		Drivers aged 66 to 75		Drivers aged over 75	
	Any change	Marked change	Any change	Marked change	Any change	Marked change
Night driving	49	13	54	14	55	13
Dawn and dusk	32	9	47	11	46	9
Rush hour	47	13	58	16	56	13
Motorway	31	9	37	10	33	10
Bad weather	31	5	35	6	32	5
When tired	52	13	56	15	54	14
In poor health	39	12	42	13	39	12
Unfamiliar vehicles	51	26	65	30	55	29
City centre	44	15	50	19	47	17
Unfamiliar areas	36	9	43	12	40	10
Country lanes	11	2	15	3	12	2
Long distances	38	12	45	16	33	14

Source: Rabbitt *et al* (1996) *When and why older drivers give up driving*. AA Foundation for Road Safety Research, Basingstoke.

Rabbitt *et al* (1996) found some, but generally small, trends with age in the percentage of drivers who had reduced their driving in specified conditions (Table 7.2).

A later study of drivers aged 50 and over (Rabbitt *et al*, 2003) found that only small percentages of drivers wanted to avoid certain situations (6.2% driving on snow, 3.5% driving on motorway, 3.4% parallel parking, 2.6% driving after dark, 2.1% reversing into a parking space, and 1.0% driving in unfamiliar areas). None of these reports separate results for men and women.

There does not appear to have been more recent work in Britain, but there are studies from Australia and the USA. A study of drivers aged 55 and over by Monash University Accident Research Centre (Charlton *et al*, 2003) found that the percentage of drivers who had reduced the amount they drove in the past five years was 38% for those aged 55 to 64, 37% for those aged 65 to 74 and 49% for those aged 75 and over. There was no difference between male and female drivers. Table 7.3 gives the reasons for driving less.

Table 7.3 Reasons for Driving Less than Five Years Ago - Current Drivers Australia, 2002 (sample of drivers n=272)

Reason	Number	Per cent
General lifestyle changes	104	38
Cut back on activities/less need	*38*	*14*
Moved house	*28*	*10*
Changed family commitments	*21*	*8*
Lifestyle changes – unspecified	*13*	*5*
Financial reasons		3
Employment changes	92	34*
Retired/semi-retired	*80*	*29*
Changed job	*12*	*4*
Health/age (of self or spouse)	45	17
Use alternative transport	35	13
Driving issues	15	6
Avoidance of certain road situations	*7*	*3*
Lack of confidence in safe driving	*1*	*4*
Other	13	5

Note: Multiple response question – total may exceed 100% for both categories and subcategories
* % category total may not equal subcategory total due to rounding

Source: Charlton *et al* (2003) An investigation of self-regulatory behaviours of older drivers MUARC Report No.208, Monash University Accident Research Centre, Clayton, Victoria.

Relationships between changes in self-assessed driving quality, frequency of driving and speed were examined. The data are presented in Table 7.4. Counter to expectation, those who rated their driving *not as good* were three times less likely to drive less than those who rated their driving as better or the same as it had been five years ago. This figure needs to be qualified by the fact that 91% of drivers reported that their driving was better

Table 7.4 Changes in driving frequency and speed as a function of changes in self-assessed driving quality – Australia 2002

Per cent of drivers

Quality of driving	Driving frequency			Driving speed		
	Driving more or same	Driving less	Total	Driving faster or same	Driving slower	Total
Better or Same	53	47	100	62	38	100
Not as Good	78	22	100	41	59	100
Total	65	35	100	52	48	100

Source: Charlton *et al* (2003)

Table 7.5 Summary of confidence ratings for driving situations
All drivers – Australia 2002

Per cent of drivers

Driving Situation	Confidence Level Very	Moderate	Not at all
Changing lanes	74	25	<1
Merging into traffic	68	30	2
Roundabouts	82	17	1
RH turns with traffic lights & RH arrow	93	7	0
RH turns with traffic lights & no RH arrow	77	23	<1
RH turns with no traffic lights	75	23	2
Intersections with no traffic lights	70	28	2
Busy traffic	71	28	2
Rain	61	38	1
Night	55	36	9
Night when wet	44	44	12

Source: Charlton *et al* (2003)

or the same as it was five years ago. Drivers who reported that their driving was *not as good* as five years ago were 2.3 times more likely to say they were driving slower compared with those who reported that their driving was better or the same as it was five years ago.

Drivers' ratings of confidence in various driving situations are presented in Table 7.5. In general, participants indicated that they were very confident in the majority of driving situations. This was particularly evident for making right hand turns with signals providing a fully controlled turning phase (93%). In contrast, fewer drivers (55%) were very confident when driving at night and only 44 percent of drivers indicated that they were very confident driving at night when wet.

Table 7.6 shows the proportion of drivers by gender and age group who state that they are 'very confident' with different driving situations. In all driving situations, the youngest group were more likely than the oldest group to be 'very confident'.

Males were more likely than females to give a 'very confident' response, particularly in the oldest age group. The report does not give results by gender and age, so it is not possible to tell whether women's confidence reduces more rapidly with increasing age than does men's.

Table 7.6 Summary of 'very confident' ratings by Gender and Age Australia

Percentage of drivers rating themselves 'very confident' in situation

	Gender		Age		
Driving Situation	**Female**	**Male**	**55-64**	**65-74**	**75+**
Changing lanes	66	79	79	74	72
Merging into traffic	53	77	78	68	62
Roundabouts	76	85	86	83	79
RH turns with traffic lights & RH arrow	92	94	96	93	92
RH turns with traffic lights & no RH arrow	70	80	86	76	70
RH turns with no traffic lights	63	82	81	76	70
Intersections with no traffic lights	60	76	75	69	69
Busy traffic	62	75	80	69	65
Rain	48	68	66	64	54
Night	39	64	63	63	43
Night when wet	25	53	48	49	35

Source: Charlton *et al* (2003)

Participants were asked if they intentionally avoid particular driving situations, Table 7.7. The majority of participants indicated that they did not avoid the various driving situations. This is not surprising, given that the majority of participants indicated high confidence

Table 7.7 Summary of avoidance of driving situations by Gender and Age Australia

Percentage of drivers who take action to avoid a particular driving situation

		Gender		Age		
Driving Situation	**Overall**	**Female**	**Male**	**55-64**	**65-74**	**75+**
Changing lanes	15	14	15	12	16	16
Merging into traffic	6	11	4	2	5	9
Intersections *	10	15	7	8	9	12
Busy traffic	22	22	22	16	26	23
Rain	14	19	11	15	11	17
Night	25	36	18	15	18	38
Night when wet	26	40	19	19	19	40

* Refers to response question regarding avoidance of any intersection (roundabout; intersection without light; intersection with light and without RH turn arrow; intersection with RH turn arrow).

Source: Charlton *et al* (2003)

and no difficulty in most driving situations. The most commonly avoided driving situations were driving at night, particularly when wet; driving in busy traffic and changing lanes. The oldest group was more likely than the youngest to avoid the various driving situations, particularly driving at night and driving at night when wet. Males were less likely than females to report avoidance behaviour.

No specific questions were asked about avoidance of particular types of intersection. However, responses relating to avoidance of “any intersections” were followed up for the types of intersections avoided. Of the 10 per cent of drivers who indicated that they avoided some intersections, the majority indicated that they avoided intersections without traffic lights (77%). Others avoided intersections without fully controlled right hand turn arrows (30%). The most frequently reported reasons for avoiding intersections were concerns for safety and crash avoidance.

Participants were asked to describe why they avoided driving situations. The most frequently reported reason cited by respondents for avoiding each of the above situations was:

- Rain – safety factors (66%)
  - *“It can be very dangerous and you can easily skid. Safety reasons.”*
- Merging – ‘personal preference’/comfort-related factors (28%)
  - *“Hate freeways. Never go on them.”*
- Busy roads – ‘personal preference’/comfort factors (40%)
  - *“Because we drive for pleasure…It’s not pleasurable to drive in busy traffic.”*
- Night driving and wet night driving – visual problems (53% and 54%, respectively)
  - *“Lights dazzle you.”*
  - *“Vision. The lights bounce off the wet.”*

Recent US publications include two by Donorfio *et al* (2008a and 2008b), cited in the references.

8. Highway Design

Britain has improved the design of highways to be easier and safer for all drivers. The USA has produced a series of 'Highway Design Handbooks' for older drivers and older pedestrians (Staplin *et al*, 1998; Staplin *et al*, 2001). The current handbook is in the process of revision, and a new edition is expected to be published late 2009 or early 2010.

Staplin *et al* (2001) covers topics such as at-grade intersections, grade separated intersections, roadway curvature and passing zones, construction zones, and railway level crossings. Within each topic, as well as making recommendations on the physical design of the feature, the section covers aspects such as traffic control devices, signing and lighting.

A number of US states have been applying the handbook since 2001, and there is beginning to be experience of the benefits achievable as a result of designing highways to take account of the requirements and abilities of older drivers and pedestrians.

Although the Highways Agency is paying increasing attention to inclusive design and the requirements of people with disabilities, Britain has nothing comparable on designing to take account of the special needs of older drivers. There would be benefit in studying the US Handbook to see whether parts of it are applicable to highways in Britain.

9. Education and training

There are many schemes to provide voluntary assessment of older drivers, opportunities for self-assessment and revision training. In USA these include the AAA Roadwise Review and the AARP Driver Safety education classes (also known as defensive driving class). The AARP course generally lasts for two days with approximately four hours daily class contact time. It can be taken in a classroom or on-line. Course objectives are:

- Updating driving skills and knowledge of road rules;
- Awareness of normal physical changes related to ageing, and what driving adjustments to make;
- Learning the warning signs which precede finishing with driving altogether;
- Reducing or eliminating traffic violations, accidents, and potential injury;
- Drive more safely on the road; and
- Obtain insurance discounts. Car insurance companies usually provide discounts to AARP graduates.

Eby at al (2008) concludes

"Are formal educational programs for older adult drivers effective? … Of those that have been formally evaluated, the research shows that educational programs:

- Increase the driver's knowledge and awareness;
- Increase safe driving behaviours, by self report;
- Improve on-road evaluation scores;
- Do not help to prevent roadway injuries; or
- May increase the number of crashes for men aged 75 years or older."

In Britain, many local authorities offer informal evaluations of older drivers and refresher driving courses. These have not been formally evaluated. Evaluation of schemes in North America show that they improve driving skills, knowledge and behaviour, but do not reduce crashes. However, in at least one English local authority an older driver programme appears to have reduced accidents involving older drivers, although this has not been formerly evaluated.

A Canadian fact sheet on older drivers (McGill University, 2007) concludes "The good news is that there is increasing evidence that older driver retraining can lead to improvements in general driving knowledge and driving-specific skills. The evidence-based recommendations to driver rehabilitation specialists … include physical training targeting flexibility, coordination, and speed of movement, as well as an educational intervention combined with an on-road component. … Overall, the results suggest that the use of skill specific training may play a critical role in the re-training of driving skills in older drivers. … The current evidence on the effectiveness of retraining aimed at older drivers is sufficiently encourageing to merit actions regarding intervention and program planning."

10. Research topics

A list of suggested research projects, based on the research reviewed in this report, consists of:

- Investigating whether the US guidelines on highway design for older drivers would apply in the United Kingdom;
- New research on self-regulation by older drivers, and particularly looking for differences between men and women;
- A study on how many male and female drivers surrender licences (and also stop driving without surrendering licences) at what ages, with some qualitative work on reasons for stopping driving;
- A study on the extent to which scooters (pavement vehicles) are substituting for cars for local journeys by older people;
- Measuring the effectiveness of local authority and other refresher training and advice to older drivers (Hampshire CC have some interesting results from the New Forest); and
- Explore why women become less safe than men after age 60 or so, and how the balance between reckless errors and misjudgement errors changes with age. Are there ways we can re-train people to avoid misjudgements, if they are the largest cause of accidents for older drivers.

Eby *et al* (2008) suggests a large number of topics on which more research is required, albeit in a North American context. These include:

Behavioural Adaptations

- More research is needed to help understand the relationship between adaptations and traffic safety.

Traffic safety

- Further research is needed on the low mileage bias using objective crash and travel data.

Medical conditions and medications

- Despite the demonstrated effect of Parkinson's disease on driving ability, there is a paucity of studies that have examined crash risk. More research is needed to understand Parkinson's disease and any associated crash risk as well as studies that address easing the transition to non-driving for those with Parkinson's disease;
- Perhaps because of impaired insight, research shows that people with Dementia/Alzheimer's do not change their behaviours after a crash. Research has shown that drivers with dementia drive more poorly than drivers without dementia. More research is needed to understand how poor driving performance in Dementia/Alzheimer's patients might or might not translate into an elevated crash risk;
- The literature investigating the associations between benzodiazepines and crash risk is rather limited. More research investigating the association between benzodiazepines and crash risk is needed;
- The relationship between drowsiness/sedation-producing antihistamines and crash risk has not been firmly established and more research is needed; and
- Use of sedating antidepressants is consistently associated with deterioration in a wide variety of vehicle-handling skills. Some studies have found that sedating antidepressants increase crash risk among older adults.

More research is needed to educate older adult drivers to use non-sedating antidepressants if they are effective; to avoid driving if they are drowsy, even if they are taking non-sedating antidepressants; and to work with their health care provider to determine their fitness to drive.

Licensing Agencies

A recent expert panel on driver licensing policy developed the following research needs:

- Design and test screening and assessment tools and/or programmes using large-scale epidemiological studies across multiple jurisdictions based on objective

measures;
- Translate research findings into specific recommendations for licensing agencies, clinicians, and other relevant organizations;
- Extend current focus on statistical significance to consider clinical usefulness (e.g., by identifying appropriate cutoffs and addressing sensitivity and specificity tradeoffs);
- Evaluate research outcomes within the context of how applicable and defensible they would be at the individual driver level;
- Expand the focus beyond individual measures of driving fitness to batteries of instruments; and
- To determine effectiveness, expand evaluation of programmes/practices to promote older driver safety and mobility.

Health Professionals

There are a number of research-related needs to enhance the health professional's ability to help maintain older adult mobility:

- Develop standardised education and training for clinicians, police officers, and licensing personnel on fitness-to-drive issues;
- Develop guidelines for licensing agencies and clinicians to refer drivers for specialised driving evaluations;
- Develop education programmes for clinicians on the requirements/policies for reporting;
- Develop methods for providing incentives for physician participation in medical advisory boards;
- Develop and provide education and training to members of medical advisory boards on issues such as driving and medical conditions; and
- Develop resources through community collaboration to support the transition from driving to alternative modes of mobility.

Education and Rehabilitation

Are formal educational programmes for older adult drivers effective? Of those that have been formally evaluated, the research shows that educational programmes:

- Do not help to prevent roadway injuries or crashes; and
- May increase the number of crashes for men aged 75 years or older.

Without further research, we can only speculate why this occurred. One possibility is that educational programmes may increase confidence in this age group, exposing them to greater risk of crash. It seems premature to give up on these types of programmes, so more research is needed in this area.

Roadway Design

Intersections

Older drivers tend to be in crashes when roadway conditions are relatively safe, such as during the day and on dry roads.

- Research needs to be done to help reduce the risk of intersection crashes including advanced vehicle technology (such as collision avoidance systems); education and training programs; and intersection modifications, such as the more frequent use of roundabouts.

Highway Design Handbook

- Individual recommendations still need to be evaluated to determine whether they are cost effective and are having the intended impacts on safety. Although some work has evaluated the older adult driver safety benefits of some of the recommendations, more research is needed in this area.

Transitioning to Non-Driving

- There is clearly a need to better understand the process of driving cessation among older adults and to identify factors that allow older drivers to successfully manage the transition from driving to other transportation options.

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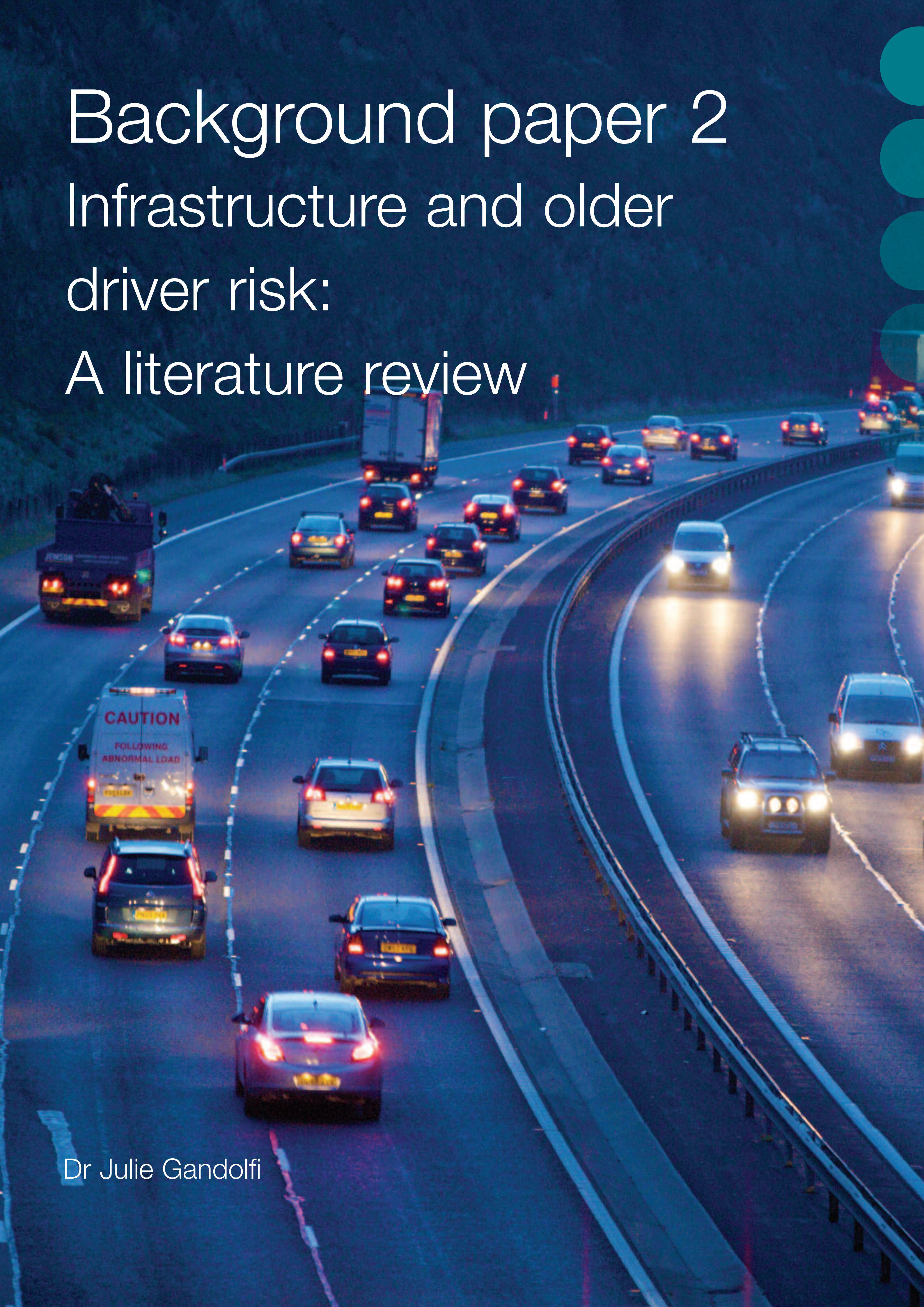
Background paper 2

Infrastructure and older driver risk: A literature review



Dr Julie Gandolfi

1. Summary of key findings relating to older driver risk and infrastructure

1.1 Summary of 'facts'

Due to the extent of previous research across the world that has been reviewed in this literature review we can safely accept a series of 'facts':

- Older drivers are more vulnerable to being involved in road collisions because of specific age-related physical and cognitive impairments which cause them difficulties and discomfort;
- When involved in a road collision, older drivers are more susceptible to serious injury and fatality due to pre-existing health conditions and general physical fragility;
- To avoid accidents, and alleviate the difficulties and discomforts of driving with physical and cognitive impairments, older drivers alter their driving habits, or cease driving altogether; and
- When older people have restricted independent mobility this causes all manner of strains to both the individual and to wider society.

There is a clear need to better understand how to develop road design that minimises the negative effects of the age-related impairments at the root of these problems.

1.2 Summary of age-related impairments

The age-related impairments suffered by older drivers fall into three key categories:

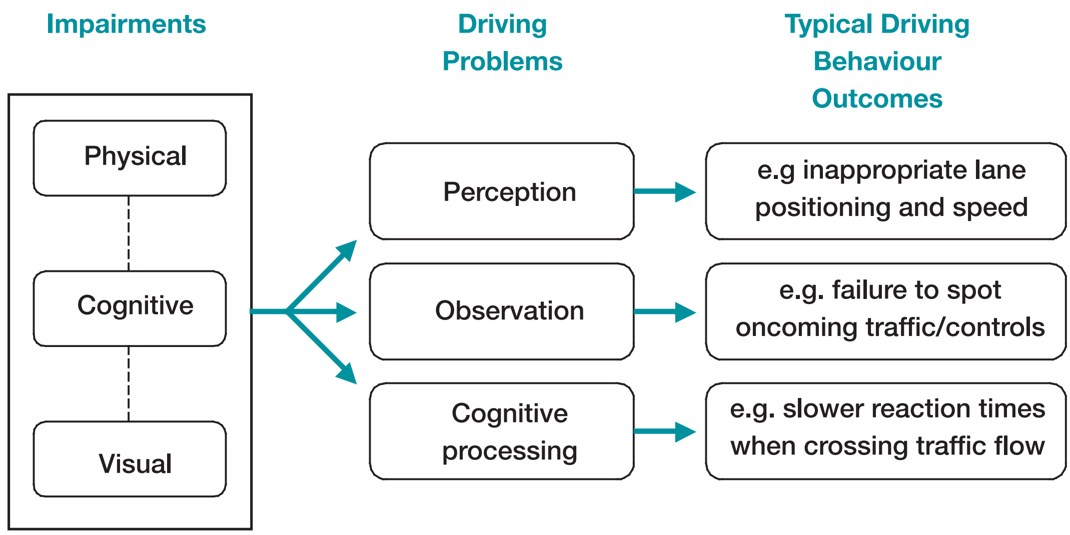
- Physical
  Restricted mobility and joint movements, particularly head and neck, preventing:
  - scanning and checking operations especially in some scenarios, and
  - physical actions such as steering wheel turning

- Cognitive
  Slower / restricted information processing capabilities require greater time and clarity for decision making and assimilation of different aspects of a situation

- Visual
  Acuity, sight distance and perception decrements prevent recognition of important design features such as channelisation, geometric shapes and sizes, and signage and markings.

Together, the various physical, cognitive and visual impairments can lead to a range of problems for the older drivers' Perception, Observation and Cognitive Processing abilities. These reduced abilities can cause inappropriate and unsafe driving behaviour outcomes. Figure 1 below illustrates this process.

Figure 1.1 Process of Age-Related Impairments Leading to Problem Driving Behaviours



As demonstrated in Figure 1, the 'typical driver behaviour outcomes' that result from age-related perceptual, observational and cognitive processing problems are varied. Whilst these relationships may seem unsurprising it is still the case that many critical features of our roads have not been designed to minimise the probability or consequence of negative driving behaviour outcomes. Moreover, although the process of impairments leading to negative driving behaviours may be unsurprising it is also often still the case that specific road design features are not designed to optimal effect.

In the following sections the relationship between each of the 'driving problems' and 'driving behaviour outcomes' that are depicted in Figure 1 are explored. The literature on older drivers and road infrastructure is used to present examples of the key perceptual, observational and cognitive processing problems experienced by older drivers and the typical driving behaviour outcomes that result. Additionally causal factors and countermeasures identified in the literature and previous research are presented.

1.3 Perception Problems

Overall problems

- Misjudging speed and distance of oncoming vehicles;
- Increased reliance on perceptual cues to compensate for observational problems and slower cognitive processing; and
- Difficulty with gap selection and turning across oncoming traffic.

Typical driving behaviour outcomes

- Inappropriate lane positioning and speed choices;
- Misinterpretation of the road environment leading to inappropriate manoeuvres (right turns, proceeding at junctions); and
- Colliding with approaching traffic on priority road when pulling out at a junction.

Causal factors

- Disorientation resulting from unfamiliar traffic systems and perceptual cues;
- Misperceived bend sharpness and consequent speed choice (not counterbalanced by perceptual indicators); and
- Problems with judgement in the dynamic traffic environment (e.g. vehicular approach speed and distance).

Contributory factors in the road environment

- Non-perceptual / non-intuitive street furniture (e.g. road signs, markings and delineation indicators);
- Non-perceptual / non-intuitive carriageway width;
- Non-delineated roads / ambiguous continuity lines;
- Non-perceptual shoulder / lane width at bends with limited supporting indicators and perceptual distractions;
- Poor long-range bend indicators (e.g. sight distance and curvature), road cross section (lane width and number of lanes), advance warning signs, separation of opposing traffic (i.e. median barriers);
- Insufficient long-range indicators to assist with lane positioning, speed choice and close range continuous lane-tracking;
- Complicated road geometry, cluttered signage and road markings (particularly in roadwork zones); and
- Unclear visual warning systems (particularly at level crossings, but this also may apply to some pedestrian crossings and road junctions).

Countermeasures suggested in the literature

- Various types of warning signs (e.g. vehicle-activated warning signs), the word “slow” prior to a bend, reflective thermoplastic road markings including a directional arrow;
- Clear, perceptual, intuitive and familiar road signs and markings (which must also apply in road work zones);
- Clear and visible guidance of appropriate path, speed and behaviour using centre lines and edge lines, narrow roads and lanes, continuous rumble strips and (in roadwork zones) flashers and median barriers where appropriate;
- Advance warning signs prior to bends; and
- Applying minimum curve length and maximum sharpness.

1.4 Observation Problems

Problems

- Failing to observe traffic approaching on the priority road;
- Failing to notice approaching traffic leaving and insufficient time to avoid; and
- Failing to observe traffic control devices.

Typical driving behaviour outcomes

- Pulling out in front of approaching traffic on a priority road;
- Carrying out a U-turn, or overtaking into the path of an already overtaking vehicle;
- Making an inappropriate right turn or overtaking/pulling out at a junction when a right-turning vehicle is masked by the glare of sunlight; and
- Causing collisions at crossroads and junctions by proceeding against traffic control.

Causal factors

Intrinsic factors include:

- Requiring greater stopping sight distance (SSD);
- Insufficient passing sight distance (PSD) to pass slow vehicles;
- Increased susceptibility to unfavourable light conditions; and
- Requiring increased sight distance of signage.

Active factors include:

- Reduced visual scanning and checking procedures (e.g. less scanning in each direction and rear-view mirror checking);
- Prioritising a single traffic stream for observations;
- Needing to use more head movements before carrying out turns; and
- Looking more frequently at the central visual area rather than the peripheral area, with longer fixations.

Contributory factors in the road environment

- Low contrast road markings lead to reduced lane-tracking;
- Insufficient use of night-time high contrast / high visibility warning signs and road delineators; and
- Poorly placed or maintained continuity lines which do not lend themselves to observation.

Countermeasures suggested in the literature

- Ensure high-contrast road markings (contrast ratio of at least 6) are used;
- Place road markings and signs in the central visual area where possible;

- Regularly maintain signs and markings to ensure sustained contrast;
- Provide plenty of high-visibility warning signs in advance of bends, junctions and other hazards; and
- Use high-contrast chevron boards and chevron plate delineators to maximise observation of bend severity.

1.5 Cognitive Processing Problems

Problems

- Reduced ability to deal with unexpected situations or unfolding emergencies;
- Requiring more time to absorb perceptual and observational information in the surrounding environment; and
- Difficulties transferring incoming information into appropriate responses, particularly remedial actions.

Typical driving behaviour outcomes

- Inattention and confusion at multi-lane road environments and junctions;
- Failure to observe traffic control signals at junctions, level crossings etc;
- Rear-end and "nearside overtake" collisions, and collisions due to over-reaction to other drivers' actions (e.g. overtaking); and
- Slow responses leading to collisions with crossing traffic at intersections.

Causal factors

- Reduced ability to prioritise information – leading to attempts to assimilate all available information resulting in much slower processing;
- Slower processing impacts on reaction time and ability to deal with emergent issues and situations; and
- Cognitive overload occurs in high-complexity situations, leading to reduced abilities and increased errors.

Contributory factors in the road environment

- Unfamiliar roads and traffic situations;
- Unfamiliar signs, road markings and traffic control devices;
- Complexity of road environment leading to high task demand and cognitive overload – due to high traffic volume and speed, restricted sight distance, inadequate intersection definition and road markings, poor channelization, road width restrictions, etc;
- High levels of construction activity in roadwork zones, combined with short duration which creates an unfamiliar situation; and
- Ambiguity of signage and road markings (especially where temporary signs/markings are in place and may be confused with existing ones).

Countermeasures to cognitive processing problems

There is little in the literature to suggest countermeasures which affect cognitive processing declines, as the driving task intrinsically requires the ability to process information within a dynamic environment and make decisions in the time constraints dictated by the speed of traffic. It is therefore likely that the most appropriate countermeasures may be to adapt drivers themselves (in terms of assessment and driver coaching) rather than road infrastructure. It has also been suggested that it may be beneficial for younger drivers to receive awareness training relating to the challenges faced by older drivers and the appropriate way to interact with their driving style.

2. Introduction

Older people have a higher involvement in fatal road accidents because they are more prone to pre-existing health conditions and fragility, and to specific age-related physical and cognitive impairments that affect driving performance (Skyving, Berg and Laflamme, 2009). In order to avoid the problems that these weaknesses bring, older drivers often alter driving habits to cope, or cease driving altogether (Raitanen, Törmäkangas, Mollenkopf and Marcellini, 2003).

Although for some older people there is simply less need to drive, particularly in post-retirement years, it is also the case that many reluctantly choose to self-regulate to avoid the discomforts and anxieties that age-related decrements cause them (Winter, 1988; Blanco, 2002). Whatever the case, loss of personal independent mobility from driving cessation can lead to mental and physical decline for the individual, including depression (Marottoli, Mendes de Leon, Glass, Williams, Cooney, Berkman and Tinetti, 1997). These individual symptoms burden both the individual concerned as well as surrounding social and support systems in wider society (Oxley and Whelan, 2008).

It is therefore in the country's interest to enable the older population to remain independently mobile for as long as possible. As there is a "psychosocial value of studying the reasons that lead to the reduction in driving" (Raitanen, Törmäkangas, Mollenkopf and Marcellini, 2003, p.91) there is inevitably also a 'psychosocial value' in studying and ascertaining which measures we need to adopt to avoid those reductions in driving. Sustaining mobility would not only enhance individuals' quality of life but would also reduce a range of psychosocial burdens (Oxley and Whelan, 2008).

Older drivers are not only more vulnerable because of various age-related health problems and fragilities, but also because of various medications they are more prone to use (Leveille, Buchner, Koepsel, McCloskey, Wolf and Wagner, 1994).

However, issues related to health can only be addressed by the healthcare system and there will be continuous calls on medical professionals to monitor individuals' physical health to assess suitability for continued driving (DfT, 2001b). There will inevitably be a vast number of older people with a lesser degree of physical and / or cognitive impairment who remain competent enough to continue driving.

We already know that age-related impairments cause particular difficulties in traffic situations that involve intersections and fast traffic (Skyving, Berg and Laflamme, 2009). We also know that road engineering and infrastructure enhancements can directly lead to safety improvements (e.g. Lord, van Schalkwyk, Chrysler and Staplin, 2007). With a better understanding of what is needed and what adaptations will meet those needs then, it would be possible to improve the driving performance and safety of impaired people and encourage them to remain active drivers.

As the world enjoys longer life expectancy and a growing older community, global interest in understanding the issues surrounding an increasingly ageing driving population has grown. In 2001 the UK Department for Transport (DfT) predicted that the existing 2 million drivers aged over 70 would increase to over 4 million by 2015 (DfT, 2001a). This obviously leads to concerns that there could be a relative increase in the number of accidents to which older drivers are particularly vulnerable, hence the scale of the need to address older driver issues.

This global interest means that there has been a growing corpus of research findings to guide practitioners in how best to adapt road engineering and infrastructure design to circumvent or reduce the effects of physical and / or cognitive impairments. However, most research has concentrated on health and physical impairment concerns rather than environmental or behavioural issues (Awadzi, Classen, Hall, Duncan and Garvan (2008). The focus of this review is therefore to examine the available literature to establish a better understanding of what wider design issues and features might warrant further consideration.

It is also the case that US based literature dominates this area of research and whilst there are studies from a variety of other countries to draw upon for broader perspective and balance, relatively little appears to have been conducted using UK-based data. We have cultural and infrastructural similarities to the US and others but the relevance of non-UK research work cannot be considered wholly transferrable. It is therefore important that further work pursues information directly relevant to UK systems with the aim of making current UK traffic infrastructures more sympathetic to the needs of older and impaired drivers.

2.1 A note on reporting systems

In a very recent piece of Swedish-based research, Skyving, Berg and Laflamme highlight a lack of detail in the information provided for accident reporting which hinders a meaningful analysis of accident reports. Specifically, the lack of detail means the authors cannot determine the extent to which any underlying health issues may have contributed to the accident in question. Thinking about this at a broader level raises the question of whether we might profit from taking a look at our UK reporting systems and the current level of information that we systematically collect. Do we gather enough information routinely with which we can truly distinguish causal factors? Further, if we do collect this data – are we processing and analysing it to provide information that would guide future policy?

3. Government Initiatives

3.1 US

A comprehensive review of research regarding the problem of older drivers in relation to road infrastructure can be found in the US Department for Transportation Federal Highway Administration's 'The Older Driver Highway Design Handbook' (2001). Previous research identified that improvements to highway infrastructure 1984-1997 had been responsible for little improvement to driver safety (Noland, 2000). So, after various other reviews and reports addressing older driver needs, this handbook was produced to present the findings of a national programme evaluating the suitability of highway design standards for the needs and capabilities of older US drivers. It aims to provide practical recommendations for highway design / traffic engineers and highway safety specialists regarding the geometrics, signing, and pavement markings in four major areas:

- At-grade intersections;
- Interchanges;
- Roadway curvature and passing zones; and
- Construction/work zones.

The handbook comprises two major sections which separate the recommendations and the supporting evidence upon which they are based. This is simply to provide a short-cut to recommendations for practitioners to use aside from the more comprehensive and detailed background information. The briefer recommendations without supporting evidence have also been produced in a separate compact version. This document 'Older Driver Highway Design Handbook: Recommendations and Guidelines (Publication No. FHWA-RD-99-045) provides individual highway designers with their own version for day-to-day activities. The full version is held by highway design agencies for reference and greater detail when required. Based on the organisational affiliations of requested copies of the handbook, it is also of interest to research organisations, universities, accident investigators and associations that represent the interests of ageing and retired people.

For the purposes of this literature review it has been pragmatic to use the FHWA handbook as a guide in this area as it appears to be the most comprehensive review of road environment and infrastructure issues specifically in relation to older drivers. However, as the FHWA handbook has been developed for a distinct and narrowly-focused US design perspective it must be kept in mind that its contents may not be wholly relevant to the UK system. For example, we did not restrict our focus to the four major areas of road design (above) and have considered wider issues of potential relevance to supporting the UK road infrastructure.

Additionally, a more recent US road design guidebook of value to this review was found at the Massachusetts Highway Department's (2006) 'Project Development and Design Guide'. This local government publication has received great acclaim and numerous technical awards for its contribution as a "national model' to road engineers and infrastructure designers. Although general and not specifically focused on the older driver, this is a contemporary review of best practice that could be helpful in considering and evaluating UK infrastructure.

3.2 UK

Several recent UK Government initiatives involving older drivers have been commissioned by the Department for Transport (DfT). This includes: '*Older people: Their transport needs and requirements'* (DfT, 2001); *'Older drivers: a literature review'* (Holland, 2001); and *The ageing driver: a programme of research'* (DfT, 2002). More recently the DfT has published *'Accidents Involving Older Drivers: An In-depth Study'* (DfT, 2009), which addresses more specifically the cause of older drivers collisions. These reports give very little attention to UK road design and infrastructure, with focus instead being on older people's general mobility and physical difficulties, particularly in relation to public transport and the pedestrian environment.

The DfT has also more recently developed strategies such as 'Towards a Sustainable Transport System' (TaSTS) 2007-8. Based on consultations which were held to gather expert opinion on a wide range of issues regarding long term transport strategy, this initiative delivers a series of proposals. However, in the main report older drivers are considered in only one area, in a cursory reference to the potential impacts of changing social demographics: *"While we expect population growth to continue, we are becoming an older society. Historically, older drivers have made fewer and shorter trips, but today older people are increasingly likely to own cars and to continue driving for longer"* (DfT, 2008, p.24).

In April 2009, the DfT published a consultation document: 'A Safer Way: Consultation on Making Britain's Roads Safest in the World'. In this document the DfT sought opinion from a wider audience, claiming: *"…we are keen to hear the views of those (expert) groups* *and of members of the public on these proposals. This input will then inform the final strategy, to be published later this year"* (DfT, 2009, p.17). However, despite having *"discussed the issues extensively with stakeholders and expert groups* (DfT, 2009, p.17) there still appears to be a distinct paucity of attention to the specific issues and needs of older drivers in the current consultation and existing proposals. Specifically, the 'older driver' is again only given cursory mention in the document's introductory accident statistics and later in a subsequent chapter on safer vehicles. In both contexts, interest is confined to concerns regarding either a) older *pedestrians*' vulnerability or b) older drivers' reduced ability to withstand collision impacts. Thus, the distinct needs of older drivers in terms of road engineering and infrastructure do not appear to be explicitly addressed by existing strategies.

Although the DfT have looked at older driver issues, UK policy in relation to sustaining mobility and older driver safety is not clear. As the DfT focuses on older drivers' higher probability of involvement in fatal accidents this perhaps indicates the policy focus: *"[W]hen statistics based on all severities are examined, there is no age-related increase in total number of accidents for the over 60s"* (Holland, 2001). Nonetheless, as the evidence to suggest that older drivers adopt coping strategies such as larger gap-acceptance or increased following distance is acknowledged (DfT, 2001), we can only assume that future policy will attend to the effects of infrastructure on these specific situations.

4. Junctions and the older driver

The Massachusetts Highway Department defines an intersection (or junction) as an area "…where two or more streets join or cross at-grade" (Massachusetts Highway Department, 2006, p6-1). Intersections involve a planned concentration of pedestrians, motor vehicles and bicycles travelling in conflicting travel directions at the same grade / level. The characteristics of intersections may differ, but the conflicting turning and crossing movements of the various traffic flows traffic are typically managed by turn-taking and capacity-limiting traffic control systems such as yield / stop signs, roundabouts and traffic signals (Massachusetts Highway Department, 2006). This makes them highly complex road environments that demand greater levels of attention and information processing than most other road situations.

Various research and statistics in the literature support the view that intersections are the most common road accident environment, across driver groups, around the world. For example, a global review of four main types of intersection[1] layout conducted over ten years ago concluded that across countries and many different types of road system,

[1] The four main types of intersection compared: *simple major / minor intersections; acceleration / deceleration lanes, central turning lanes; roundabouts* (O'Cinneide and Troutbeck, 1998)

intersections present *"the most dangerous part of the road network"* for drivers around the world (O'Cinneide and Troutbeck, 1998, p.8). For many years research has been showing how intersections (controlled and non-controlled) present an especial challenge for all road users (e.g. Björklund and Åberg, 2005). Other research has pinpointed that in different countries a substantial proportion of accidents occur in urban intersection settings (e.g. Al-Ghamdi, 2003; Corben, 2006).

In the US the FHWA reports that 21% (8,657 people) of all road fatalities in 2007 occurred at, or were related to, intersections and importantly that: *"[D]espite improved intersection design and more sophisticated applications of traffic engineering measures, the annual toll of human loss due to motor vehicle crashes has not substantially changed in more than 25 years"* (FHWA, 2009). Clearly then, intersection environments still present the most difficult circumstances for drivers to negotiate and we are lagging behind in developing relevant safety improvements as we have in other road safety areas.

Given that intersections are disproportionately associated with the driving difficulties and accident involvement of drivers in general, it is unsurprising that we find older drivers are particularly more prone to intersection accidents (Preusser, Williams, Ferguson, Ulmer and Weinstein, 1998). It has been predicted that over 40% of all fatal crashes may be attributable to age by 2025, particularly in respect to various visual and cognitive impairments (Staplin, Lococo, Gish, & Decina, 2003). Due to these impairments the difficulties that make these traffic systems particularly problematic for the older driver involve scenarios where gap selection and turning across oncoming traffic appears to be the most difficult (Oxley, Fildes, Corben and Langford, 2006). More recent US research exploring the nature of intersection negotiation revealed that older drivers may use different visual scanning and checking procedures (Bao and Boyle, 2009).

Across the world, it appears that the various intersection design standards have developed from local "logical assumptions and expectations" rather than from empirical information such as accident statistics and research, so there is a need for empirical work to be conducted in the context of individual countries, which specifically attends to older driver vehicle usage (O'Cinneide and Troutbeck,1998).

Older drivers have proportionately more low speed crashes at intersections during daylight (Preusser *et al*, 1998). Additionally, older drivers, in particular, have been found to be at higher risk of being killed in a traffic crash occurring in rural areas than in urban settings (Clark, 2001), but the main risk appears to be in interacting with other traffic in situations such as intersections, as single vehicle crashes have been reported to account for less than 7% of older driver crashes (McGwin and Brown, 1999). It has been concluded that older drivers have problems in all turning situations, especially in right turns (in the UK and other countries that drive on the left) and to some extent in changing lanes. Preusser *et al* found that right turns were a common problem for older drivers at signalised intersections, and Knoblauch *et al* (1995) reported that an excess of crashes occurred among older drivers both when pulling out and turning in at stop-sign controlled intersections. When pulling out at intersections, older drivers are more likely to be struck on the drivers' side of the vehicle, as it is exposed to the most immediate threat of oncoming traffic (Preusser *et al*, 1998).

Boufous *et al* (2008) reported that that collision rates for older drivers at intersections were much higher when traffic controls such as traffic lights were not present. Older drivers' visual, perceptual and reaction time decrements lead to a large proportion of their collisions at intersections being classified as their fault, especially when the collision involves a driver proceeding through a red traffic light or a stop sign. Preusser *et al* reported that when drivers aged 85 and older were compared with drivers aged 40 to 49, the older group were blameworthy in 7 collisions for every collision in which they were non-blameworthy, while the younger group were responsible for just 1 in 5 of their collisions. The over-representation of older drivers in collisions at intersections is reflected by the typical speeds involved in older drivers' impacts – they are far more represented in collisions at less than 30mph than at higher speeds, and their involvement decreases with increasing speed (McGwin and Brown, 1999). Preusser *et al* found that 80% of fatal collisions involving drivers over 65 emerging inappropriately into the traffic stream occurred at intersections, while the rest involved driveways and other entrances.

Around 50% of the intersections had stop signs, 23% were under traffic light control, 20% had no traffic control devices, and 7% were controlled by other kinds of device such as a "give way" sign or flashing beacon. These findings indicate that the majority of traffic control devices are not sufficiently effective in preventing older drivers from proceeding when it is not safe to do so. When drivers reach the age of 75, more than 50% of their fatal collisions involve running traffic control devices, but the proportions of head-on collisions and run-off-road incidents decline (Preusser *et al*, 1998).

Langford and Koppel reported that older drivers were more than twice as likely to be involved in a collision caused by one vehicle turning right into the path of an oncoming vehicle, and they were also more than twice as likely to be involved in a right-angle collision at an intersection where they were proceeding straight ahead and were struck by a vehicle proceeding straight ahead from an adjacent road. Langford and Koppel also reported that they were five times as likely to turn right across the path of a vehicle proceeding straight ahead from an adjacent road at an intersection. Hakamies-Blomqvist (1994) explains this kind of collision in terms of older drivers entering an intersection without obeying the right of way of vehicles approaching on the priority road.

Much research tends to assume that the older driver is solely responsible for the collisions that are classified as being at-fault, but it is important to note the social framework involved in driver interaction and the role that other drivers may play in collision causation and/or avoidance. For example, Langford and Koppel reported that older drivers tend to have a higher proportion of collisions with young drivers aged 17-25 compared with their middle-aged counterparts, but the older drivers had a lower proportion of collisions with other older drivers (3% for older drivers, 9% for middle-aged drivers). Lanford and Koppel explain this in terms of the riskier driving practices of the younger driver group, and the inability of older drivers to respond to it appropriately. They also suggest that older drivers are making errors that are not easily dealt with by younger drivers, whereas other older drivers are accustomed to the more cautious driving style and therefore deal with any errors efficiently. Keskinen, Ota and Katila (1993) found that older drivers accelerated more slowly when turning compared with younger drivers, who approach intersections more quickly thus increasing the likelihood of a collision between members of those two groups. Therefore a collision that may be deemed the fault of the older driver for pulling out across the traffic stream may have been contributed to by a younger driver failing to adapt their driving style to meet that of the older driver.

More recent US research exploring the nature of intersection negotiation revealed that older drivers may use different visual scanning and checking procedures (Bao and Boyle, 2009). Crash rates at intersections are relatively high, especially at rural non-signalised intersections, resulting in considerable numbers of fatalities annually (Burgess, 2005). Problems at intersections generally involve visual issues and include failure to observe relevant traffic signs or signals (McGwin and Brown, 1999), traffic approaching on the priority road (Caird *et al*, 2005), or failure to judge speed and distance of oncoming vehicles (Guerriera *et al*, 1999). Lack of observation of approaching vehicles was classified as the key causal factor of intersection crashes in the New Zealand Land Transport study (2005).

Differences in visual attention have been observed at T-junctions, with drivers displaying significantly more head movements to the right before carrying out left turns compared with right turns (Summala *et al*, 1996). Studies have indicated that older drivers look less towards their peripheral area than their central visual area, and display significantly longer fixations (Maltz and Shinar, 1999). Search errors are also more prevalent in older drivers compared with younger drivers (Ho *et al*, 2001). Bao and Boyle (2009) reported that older drivers scanned in each direction significantly less than middle aged and younger drivers at intersections, and the older drivers prioritised one traffic stream for their observations, and they were less inclined to check their rear-view mirror regularly, indicating that their all-round observations were not suitably comprehensive prior to negotiating the intersection. Bao and Boyle (2007) studied differences in visual search durations between older drivers and middle aged drivers at a rural intersection, and found that older drivers did not utilise as much search time. Research has indicated that collisions at intersections, particularly complex and demanding ones, are common among older drivers due to functional deficits – a combination of visual acuity, peripheral vision, cognitive impairment, decision-making errors and attentional problems, leading to a failure to notice an approaching vehicle or noticing it so late there was insufficient time to take avoiding action (Isler *et al*, 1997; Caird *et al*, 2005).

The pace at which an intersection is negotiated is not specified by the individual driver, and the slowing of cognitive processing and reaction time associated with ageing does not lend itself to the safe negotiation of intersections under time pressure from other vehicles. Several tasks are involved in dealing with an intersection, and the amount of time allowed depends on the road layout, vehicle speeds on approach to the intersection, and proximity of other vehicles, placing heavy cognitive load on the driver (Hakamies-Blomqvist, 1996). In this situation, age-related or illness-related declines have a negative effect on performance and increase propensity to make mistakes (Hakamies-Blomqvist and Henriksson, 1999). If the sub-tasks involved in dealing with the intersection take a long time, the gaps in the traffic may not be sufficient to allow the older driver to pull out safely and confidently (Keskinen *et al*, 1998). The usual coping strategy employed by older drivers – operating at lower speeds in order to gain more time to carry out each task – is not an option due to the demands of the situation (Cooper *et al*, 1993; Hakamies-Blomqvist, 1994b).

Other drivers may bear greater responsibility for older drivers' problems than is widely acknowledged. Bjorklund and Aberg (2005) carried out a study of self-reported behaviour at a crossroads on which there was no clear priority. Drivers' behaviour was varied depending on a number of factors, including cues from the behaviour of other drivers and the width of the road. Sub-groups of drivers could be identified according to their behaviour – one group reported rarely giving way to other drivers, while another reported always giving way.

These variations between drivers add to the potential confusion for an older driver presented with an already high-workload situation. However, there may be times when other drivers do compensate for the behaviour of the older driver – Preusser *et al* reported that older drivers are less likely to be struck on the passenger side of their vehicle, and suggest that it may be because drivers approaching the intersection on the far side of the carriageway have more time to see the emerging vehicle and take avoiding action.

Analysis of driver movements indicates that older drivers are five times as likely to be in a vehicle making an inappropriate right turn than in the vehicle proceeding ahead (28% of older driver crashes compared with 5% of middle aged drivers') (Langford and Koppel, 2006). The impact points of the vehicles support this finding – the authors report that older drivers are three times more likely to be hit on the drivers' side, and 1.5 times more likely to be hit on the passenger side compared with middle aged drivers, indicating a failure to give way to the right when turning left and turning right against oncoming vehicles. Side-impacts account for 36% of older driver collisions and 15% for middle aged drivers. McGwin and Brown found that older drivers were less likely to sustain impact on the front of their vehicle compared with middle aged and younger drivers, indicating they were more likely to be hit than to hit another vehicle, although the front corners were more common impact points.

In terms of fatal crash risk at intersections, drivers aged 85 and older had a relative risk of 10.62 times that of drivers aged 40 to 49, compared with a relative risk of 3.74 for other crash types (Preusser *et al*, 1998). The large number of older driver crashes involving failing to give way, failing to obey stop signs, lack of observation of objects and other vehicles, changing lanes inappropriately and pulling out in front of approaching traffic indicating that older drivers do indeed suffer perceptual problems and have difficulty responding to the traffic environment (Kline *et al*, 1992).

Older drivers are strongly over-represented in crashes involving turning across oncoming traffic, turning across adjacent traffic flow, or entering an intersection at the same time as another vehicle from a different direction (Langford and Koppel, 2006). Preusser *et al* explain that the increased risk of fatal crash involvement may be the result of intersection-specific driving errors brought on by the ageing process, or it may be due to changes in driving exposure meaning that older drivers are in risky locations at risky times, e.g. low speed city intersections during the daytime, where high incidence of multiple vehicle collisions occur. Preusser *et al* also suggest that the increased risk may be due to driver frailty, resulting in fairly low-speed intersection collisions resulting in serious injury or death.

The US FHWA handbook cites numerous research findings to highlight how both older drivers and pedestrians are especially more vulnerable to accidents involving highway intersections in the US. In particular, 17 design elements / manoeuvres are considered in relation to specific age-related difficulties:

- Intersecting angle (skew);
- Receiving lane (throat) width for turning operations;
- Channelisation;
- Intersection sight distance requirements;
- Offset (single) left-turn lane geometry, signing and delineation;
- Treatments / delineation of edgelines, curbs, medians and obstacles;
- Curb radius;
- Traffic control for left-turn movements at signalised intersections;
- Traffic control for right-turn/RTOT movements at signalised intersections;
- Street-name signing;
- One-way / wrong-way signing;

- Stop- and yield-controlled intersection signing;
- Devices for lane assignment on intersection approach;
- Traffic signals;
- Fixed lighting installations;
- Pedestrian crossing design, operations and control; and
- Roundabouts.

Across all of these various manoeuvres, a set of age-related physical and cognitive impairments are associated with the difficulties to which older drivers are more vulnerable, namely mobility, cognition, and sight:

- Restricted mobility and joint movements, particularly head and neck, preventing: a) scanning and checking operations especially in some scenarios and b) physical actions such as steering wheel turning;
- Slower / restricted information processing capabilities, incurring greater needs for time and clarity for decision making and assimilation of different aspects of circumstances; and
- Visual acuity, sight distance and perception decrements which prevent recognition of important design features such as channelisation, geometric shapes and sizes, and signage and markings.

US research indicates that older drivers are more likely to be involved in turning and angle collisions at urban and rural intersections because they fail to yield or start from a stop position adequately; it seems they cannot easily estimate the speed of target vehicles or distinguish vehicles amidst the visual confusion of the scenario (FHWA, 2006b). This can be made worse by the obstruction of other cars turning at signalised intersections (Yan and Radwan, 2007).

An in-depth task analysis study (FHWA, 2006a) has shown that time constraints, where there is a limited amount of time available to perform many varied but necessary tasks, is a key consistent problem across intersection driving scenarios: *Approach, Prepare for Lane Change, Execute Lane Change, Deceleration/ Stop, Decision to Proceed, Intersection Entry, Prepare for Turn, Execute Turn.* Clearly, these tasks involve a considerable degree of information processing and decision-making that make the time pressure more critical. These driving tasks *"draw on the same perceptual and cognitive resources, which leads to more time-consuming sequential execution and also increases the potential for "interference" between tasks"* (FHWA, 2006a, p.161). This task analysis approach supports the findings of much other research that has indicated that intersections present the most demanding and complex driving environments. The cognitive demands and time constraints of intersection driving also helps to explain why wider research has often attributed older drivers' intersection accidents to age-related declines in selective and divided attention (e.g. Caird, Edwards, Creaser and Horrey, 2005).

All of these problems can cause older drivers to take inappropriate actions. Older drivers may directly compromise their own safety or confuse other drivers which has wider implications given that intersections rely on formal and informal rules and expectations (Björklund and Aberg, 2005). In terms of visual and cognitive impairments, a general theme throughout the FHWA handbook is that the clearer and more easily discernable a road structure is, the less cognitive effort and time will be required to negotiate it. Additionally, physical impairments to which older drivers are prone affect their vehicle handling difficulties and behaviours which compromise safety.

Research conducted in Japan suggests, contrary to other research, that there may be no significant differences in the attentional behaviour / capabilities of older drivers but it is more likely that they simply do not react and turn quickly enough (Keskinen, Ota and Katila, 1998). These authors point out that this delayed or slower action may be an even greater concern when the oncoming traffic involves younger drivers who, contrastingly, tend to drive at greater speeds. Again, this suggests a probable combination of physical mobility restrictions and some sort of perceptual or visual decline.

A key factor in urban intersections road collisions appears to be drivers' failure to obey traffic control devices, (Retting, Ulmer and Williams, 1999), and particularly failing to stop (Retting, Williams, Preusser and Weinstein, 1995). Recent simulator-based research also indicates that older drivers approach traffic lights more slowly and accurately, but are also less likely to stop at the amber light compared to younger age groups (Caird, Chisholm, Edwards and Creaser, 2007). This means that older drivers were found more likely to be travelling through the intersection when the red light shows, implying that unintentional violations lead to older driver intersection errors, probably related to the various other age-related impairments to which we refer.

Analysis of Australian formal accident investigation data by Oxley *et al*, (2006) led to the following estimation of factors contributing to intersection crashes (weighted by exposure and crash involvement at various sites):

The same study put forward that the three design features most likely to contribute to older driver crashes included “a lack of use of separate signals to control movements in each turn lane, restrictions in available sight distances at right-turn intersections, and an insufficient perception–reaction time distance for intersection sight distances” (Oxley *et al*, 2006).

The evidence clearly shows that intersections are a universal problem – both globally and across driver groups. Whilst there are general principles we can transfer from US / global research and statistics it seems clear that no foreign initiatives have yet been very successful at improving these traffic situations. So, whether or not other nations’ systems are different or comparable to our own we need to bear in mind that we still have yet to

Table 4.1 Factors contributing to intersection crashes

Factors contributing to intersection crashes	% of cases
Inappropriate gap selection	76%
High task complexity and the presence of other road users	50%
High approach speeds of conflicting traffic	40%
High traffic volumes	40%
Limited or restricted sight distance	34%
Inadequate intersection definition	8%
Red-light running/inappropriate response to signals	8%
Inappropriate pavement markings	8%
Poor channelisation	6%
Road width restrictions	6%

Source: Oxley *et al* (2006)

find successful systems at junctions. The DfT literature review found that fatal accidents involving older drivers generally occur in daylight, at intersections and at low speeds (Holland, 2001) but does not provide much more information. It therefore seems appropriate that whilst we continue to look at any emergent research and new indications it might also be sensible to concentrate on seeking in-depth data and developing systems within the UK.

It is also the case that successful intersection driving depends on familiarity and informal rule compliance (Björklund and Åberg, 2005). It is therefore important to understand how UK roles are understood, and complied with, across different environments and scenarios.

4.1 Type of road / Intersection control system

Research has, across driver groups, generally indicated that more complex road environments create higher accident involvement. Unsurprisingly, the older driver tends to find these more complex situations increasingly problematic (Korteling, 1994). Recent findings suggest that older drivers negotiate intersections according to their familiarity / habituation and whether their usual locale is urban or rural (Keay, Jasti, Munoz, Turano, Munro, Duncan, Baldwin, Bandeen-Roche, Gower and West, 2009). Preusser *et al* reported that older drivers under 80 found negotiating junctions with no traffic control to be the most risky, followed by those controlled by a stop sign, then traffic light control. Over-80s displayed greatest risk at stop-sign controlled intersections, followed by uncontrolled junctions and proceeding straight ahead at junctions.

Keall and Frith (2004) found that, when accounting for other variables such as time, exposure, locale, etc., older drivers experience less risk when using motorways. This implies that despite the higher speeds experienced on this type of road environment the older driver may be safer because there is in most conditions less complexity e.g. signage, intersection, control system, other directional traffic, etc. When on the motorway, older drivers are probably safer because they have only to negotiate forward traffic and a relatively simple traffic control structure. It may therefore be beneficial to more comprehensively explore the effects of road type to ascertain what is helpful to older drivers as opposed to what is particularly unhelpful to their driving performance and confidence. Preusser *et al* suggest that all the relevant information required to traverse an intersection should be made clearly available by looking straight ahead at signals, which would be beneficial for younger and older drivers alike.

At non-signalised intersections, it is suggested that four-way stop signs are used, as they would reduce the decision requirements and increase the time available to deal with the junction as approach speeds would be reduced from all directions. One-way streets intersecting with other one-way streets can reduce information requirements by half. Preusser *et al* point out that whilst these kinds of measures may be currently viewed as excessively costly and inefficient, decisions about cost-effectiveness may need to be reconsidered soon due to an ever-ageing population. Lord *et al* (2007) strongly advocate the replacement of many existing intersections with roundabouts – as they have been shown to display significant improvements to intersection safety (Persaud *et al*, 2001; Flannery, 2001). The reduced number of conflict points on a roundabout, and the uni-directional movement of the traffic means that frequency and severity of older driver crashes may be reduced. Lord *et al* highlight requirements of roundabout design to make it self-explanatory for older drivers, such as advance signage, lane advice, direction of travel, priority, exit signage, and guidance on lane position at the roundabout. Lord *et al* also advocate education of older drivers at a broad level in an attempt to minimise older driver risk. Staplin *et al* (2001) noted that in addition to improving geometric factors and traffic control devices, there may be other low-cost interim measures that would be beneficial for older drivers, for example to increase sign luminance, increase reflectivity of road markings, increase the size of road signs and reconsider sign placement.

5. Roadway curvature and overtaking

The FHWA report on road infrastructure and older drivers in the US highlighted four key issues in this area – roadway marking and delineation, carriageway width, curve length and advance signage, and overtaking zone length. Each of these elements is important for all road users, but the physical and cognitive declines associated with older drivers mean they may rely more heavily on perceptual cues provided by the road environment. Consequently the "self-explaining roads" (SER) approach (Theeuwes and Godthelp, 1995) may be beneficial for older drivers.

A key element of the SER approach is the idea that road characteristics such as road markings, carriageway width, road signs, street furniture and other perceptual features act as integrated indicators to the way in which drivers should interact with a stretch of road or traffic environment (van der Horst and Kaptein, 1998). The road and the surrounding environment provide essential information to help the driver establish appropriate behavioural limits and avoid risky actions (Saad, 2002). Studies have established the utility of SER designs for speed management (Elliott, McColl and Kennedy, 2003; Elvik, 2001) and for influencing drivers' lane positioning (Davidse *et al*, 2004). However, this approach requires consistent design across the road network, as driver expectancy and geometric consistency are important because inconsistencies can result in confusion (a particular risk for older drivers) and lead to errors that increase collision risks.

5.1 Roadway marking and delineation

Road marking has been shown to be the most important characteristic in driver recognition of road types (Davidse *et al*, 2004). Adequate roadway delineation can provide long-range guidance for drivers in terms of lane positioning and speed choices, and facilitate continuous lane-tracking at close range (Scheiber, 2000). De Waard *et al* (2004) demonstrated that adding painted material to the road surface affected position on the road – while drivers took a fairly central position on a non-delineated road, adding a centre line to divide the road into two lanes encouraged drivers to remain in their lane and thus drive closer to the edge of the road. McKnight *et al* (1998) found that white lines with low contrast reduced lane-tracking performance compared with higher contrast lines – a finding which is likely to be particularly pertinent to older drivers due to well-documented visual decrements associated with increasing age, particularly in low-light conditions (Gandolfi, 2010).

Diverge and merge continuity lines have been shown to keep drivers in lane when roads gain or lose a lane and to reduce overall speeds and overtaking rates, as well as headway distances (Charlton, 2007b). In terms of merging behaviour, a hatched runout at the end of a multi-lane section was associated with earlier merging and longer headway distances. Increasing headway is important for older drivers due to their propensity to be involved in rear-end collisions (Gandolfi, 2010). Simulator studies have shown that continuity lines appear to encourage drivers to avoid crossing lane lines, even when they are not given explicit instructions relating to the intended meaning of the continuity lines or the behaviour expected of them in response to the road markings (Charlton, 2007b), supporting their utility from an SER perspective. Additionally the continuity lines helped to compensate for absent perceptual information in areas of reduced visibility (resulting from topography or road geometry), which is likely to be particularly useful for older drivers as they provide a clearly visible and unambiguous instruction.

Advance bend warning signs are more often consciously detected by drivers compared with chevrons placed at tangent points (Charlton, 2006), but they are far less effective at reducing speeds into the bend (Charlton, 2004). It has also been reported that highlighting perceptual features of a bend through road markings has a greater effect on driver behaviour than advanced warning signs indicating the severity of the bend (Charlton, 2007b). Lewis-Evans and Charlton (2006) reported that drivers rely heavily on habit and proceduralised approaches to maintain speed and lane position, and consequently fail to consciously monitor and process the meaning of many advance warning signs. Warning signs that highlight or delineate the sharpness of the bend provide perceptual cues that are processed at a more fundamental level, thus appearing to overcome this problem (Charlton, 2007), and may provide particular insight to older drivers who may have difficulty assimilating all the integral perceptual cues on entry to a bend.

5.2 Road width

The effects of road width on speed appear to be related more strongly to implicit perceptual factors than to drivers' explicit consideration of risk (Lewis-Evans and Charlton, 2006). The perceptual cues involve unconscious processing of edge rate information in the peripheral vision and are the reason that driving in a narrow road or tunnel often results in an exaggerated sense of speed (Lewis-Evans and Charlton, 2006). Deceleration can result in a visual motion after effect (VMAE) which in turn can lead to a significant underestimation of speed – a significant risk when decelerating for a curve approach (Charlton *et al*, 2002). Charlton (2007b) points out that it is an interesting paradox that features of the driving situation that go relatively unnoticed can have such a powerful effect on drivers' behaviour.

Narrow roads can lead to a temporary loss of visibility, during which the driver is unable to see if a vehicle is approaching. The influence of the road environment in narrow lanes tends to cause drivers to move towards the centre of the road, thus risking a collision with an opposing vehicle (Blana and Golias, 2002: van Driel *et al*, 2004). Alternatively the surprise appearance of an unexpected oncoming vehicle can lead to a steering over-correction leading to a run-off-road incident. These are particular risks for older drivers as a result of age effects on reaction time and potential declines in motor skills.

Although increases in lane and shoulder width have been recommended as a way of making bends more forgiving (Zegear *et al*, 1990), which is likely to be of benefit to older drivers, this approach can also have the effect of increasing drivers' speeds, thus negating any overall safety gains (Lewis-Evans and Charlton, 2006). Increasing lane width on bends may also lead to misperceptions of curvature, which is reported to be a common characteristic of high-accident bends (Shinar, 1977). Drivers have been found to reduce speed more significantly for bends that are perceived as being sharper (as for roads that appear narrower), but the perceptual characteristics that produce the perceived level of sharpness for a bend are not clearly defined (Shinar *et al*, 1980). Given older drivers' tendency to exhibit perceptual errors, it is therefore important that any ambiguous perceptual cues are overridden by road markings, signage and other clear and explicit measures. For example, Charlton anticipated that the use of herringbone road markings to effectively narrow lane width would reduce speeds and provide drivers with guidance relating to the optimal path through bends. Their study did not produce any significant speed reductions, but they reported profound effects on lane positioning. They concluded that potential speed reductions from lane narrowing may have been offset by the provision of an optimal path through the bend which encouraged greater speeds. When used in combination with chevron signs and repeater arrow signs, the herringbone markings achieved a reliable reduction in speed as well as an improvement in lane positioning.

5.3 Curve length and advance signage

There is evidence that road structure, including curvature and frequency of junctions, may influence the risk of collisions (Wong and Nicholson, 1992). Older drivers may not have suitable observational or cognitive processing skills to deal with a high frequency of bends and junctions, or it may be that they do not have the ability to react to a stimulus and implement steering quickly enough (Keskinen *et al*, 1998). Collision analysis indicates that many crashes happen when drivers are negotiating a bend (Bar and Page, 2003; Larsen, 2004; Kim *et al*, 2007), with sharp bends displaying greater likelihood of collisions than gentle bends (Walmsley *et al*, 1998; Ikeda and Mori, 2005). Barker *et al* (1999) found that a third of all rural single carriageway collisions happened on a bend, and these crashes were more serious than average. Serious crashes are more likely to result in fatalities for older drivers compared with younger drivers, due to their increased frailty (Staplin *et al*, 2001). Modern roads are less risky than older routes, partly due to improvements in road design such as reductions in horizontal curvature (Walmsley and Summersgill, 1998). McDonald (2004) reported that for single vehicle accidents, there is a 34% increase in accident frequency per sharp bend per kilometre. Consequently it is logical to assume that areas containing roads with many sharp bends will display higher collision rates than those with straighter roads, however the relationship between collision frequency and the road structure is complex. Shankar *et al* (1996) and Hughes and Amis (1996) show that more acute bends display lower crash risk, which is attributable to speed reductions in response to their sharpness, while Johnston (1982) reported that bends requiring substantial speed reduction were overrepresented in crash statistics (which may mean harsh braking and increased risk of rear-end collisions for older drivers). It is possible that methodological differences have influenced the outcomes of these studies, but there is clearly a complex mechanism underlying crash risk on bends, which has not been clarified particularly in relation to older driver risk.

Milleville-Pennel *et al* (2007) stated that collisions may be the result of inaccurate anticipation of a bend due to the misperception of a bend's properties together with an underestimation of the risks associated with the particular bend in question. The likely outcome of these inaccuracies is excess speed into the bend. Drivers' paths through bends often increase friction demands well beyond those anticipated by road designers by overshooting the curve and producing a vehicle path that is sharper than the actual radius of the bend (Neuman, 1992). Unfortunately it appears that drivers often underestimate their speed through bends, particularly when travelling at higher speeds (Milosevic and Milic, 1990). Some researchers have suggested that this may be attributable to motion perception cues specific to the deceleration process of a curve approach (Charlton, 2007). Misperception of speed and bend sharpness (Johnston, 1982) and inability to meet increased attentional demands (McDonald and Ellis, 1975) can be compounded by drivers' inability to maintain appropriate lane position through the bend (Good, 1978), resulting in a loss-of-control or head-on collision (Charlton, 2007). Attentional failures may be a particular problem for older drivers in general, which can impact upon absorption of information from perceptual cues and compromise judgement in terms of speed choices and lane positioning on bends. Successfully negotiating a bend requires drivers to anticipate the bend by adjusting their speed and lane position to accommodate the sharpness of the bend (Reymond *et al*, 2001), thus requiring greater attentional resources than driving on a straight road.

When attention is diverted or attentional resources are diminished, crash risk increases significantly (Knowles and Tay, 2002), as a result of an inability to respond to hazards in a timely manner and impaired judgement as a result of diminished information gathering and processing, meaning that drivers may fail to notice warning signs and other cues required to anticipate bends.

Four key factors are important in the maximising safety on bends – sight distance through the bend (curvature), road cross section (lane width and number of lanes), advance warning signs relating to the bend, and the separation of opposing traffic i.e. median barriers (Kanellaidis, 1995). When drivers were classified as violators or non-violators (in terms of propensity to obey speed limits), it was found that advisory speed signs at bends were the most important variable in determining speeds for non-violators, whereas for violators the road layout was the most important factor. Typically older drivers are not prone to violations and it is therefore reasonable to assume that they respond well to advisory speed signage.

Haynes *et al* (2008) reported that there is no evidence that areas with lots of bends had more collisions compared with other areas, in fact the urban areas with the straightest roads had significantly more crashes that the urban areas with more bends. This supports the idea that road curvature may have a protective effect in urban settings. Equally Haynes *et al* (2007) did not find that roads with more bends displayed greater crash risk, instead the number of crashes was inversely related to road curvature. The most important factors were found to be the cumulative angle turned per kilometre and the length of segments of road in relation to straight-line distance. These findings imply that the combination of bend sharpness and bend frequency is important in determining crash risk. The negative relationship applied to fatal, serious and slight injury collisions over major and minor roads, indicated a twofold difference in crash rates. Whilst acknowledging that individual bends can be dangerous, these findings support the protective effect of road curvature over large areas, but no investigation or analysis specific to older drivers was carried out. Possible mechanisms for the effect may include speed reductions, increased driver vigilance, and discouragement of risk-taking behaviours (Haynes *et al*, 2008), and new interventions to reduce crashes may target these factors through education and enforcement rather than engineering. However, this area requires further investigation as, while Haynes *et al* (2007) reported a general protective effect in England and Wales, Haynes *et al* (2008) found that in New Zealand the effect was restricted to urban areas. This may be a product of methodological differences but a detailed UK analysis directly comparing urban and rural crash risk relating to bend severity and frequency would clarify the situation.

Various measures have been implemented to try to make drivers more aware of the existence and severity of bends, particularly in terms of signage and road markings. Findings relating to the extent to which older drivers respond to road signage have been mixed. Some research indicates that older drivers have problems with recognising and understanding road signs (Richards and Heatherington, 1998) or may even ignore them (Otani *et al*, 1992), while other research supports the conscientiousness of older drivers and shows that they are more likely to respond to signs in order to comply with the rules of the road (Al-Madani and Al-Janahi, 2002).

According to Hoc (2005), cognitive processing relating to bend awareness and assessment can be divided into two levels – subsymbolic and symbolic control. Subsymbolic control relies on information that has significance by itself, i.e. road curvature, which does not require major interpretation.

Symbolic control involves using signs and concepts which do not have significance in themselves and require interpretation, such as a road sign, which allows the driver to identify meaning and use their knowledge and experience to predict the properties of the bend and treat it accordingly. Symbolic road signs have been found to be a useful way of improving bend curvature assessment (Charlton, 2007), so warning signs are placed along the road prior to a horizontal bend, to alert drivers to the change in road angle and remove the element of surprise (Donald, 1997). Unfortunately some research indicates that the signs do not seem to have a dramatic effect on drivers' perception of the risk associated with the bend, as they have been found to display safety improvements of only 6% (Jorgensen and Wentzel-Larsen, 1999), although others report that curve severity and hazard estimates increase in the presence of signage (Milleville-Pennel *et al*, 2007). The minimal effect on safety improvements may be due to differences between how groups of drivers approach the bend. Older drivers tend to take a more cautious approach to driving anyway, and may rely more heavily on subsymbolic information where available, turning to symbolic information only in the absence of other perceptual cues.

It is likely that the approach speeds of many drivers of all ages is appropriate for the bend regardless of the existence of signage, as they have chosen to err on the side of caution having assimilated all available information anyway (or indeed reacted to the lack of perceptual cues). The benefit could be attributed in its entirety to a sub-group of drivers who do not utilise subsymbolic cues or indeed reduce speed in reaction to a lack of subsymbolic information, but who do react to road signage. It is possible that the reductions in cognitive processing capacity and consequent driving performance decrements associated with increased age (Shinar, 1993; Colsher and Wallace, 1993) may lead some older drivers to prioritise road signs in order to gain information about risks on the road and to comply with the law.

Increasing stopping sight distance (SSD), where possible, has also been promoted as beneficial for safety on bends. SSD is defined as enough sight distance to permit drivers to detect an unexpected or ambiguous source of information, recognise it, and be able to stop in response to it, under reasonable worst-case conditions (Staplin *et al*, 2001; Texas DoT, 2006). Adequate SSD allows the driver to plan and maintain an appropriate trajectory, as they are equipped with the relevant perceptual information to deal with the bend appropriately. The SSD required by an older driver may be greater than that required by a younger driver, due to age-related decrements in cognitive processing ability and reaction time. Older drivers tend to prioritise accuracy over speed in task performance (Welford, 1962; Rabbitt, 1965) which means that they tend to make absolutely sure that they have accurately comprehended a situation before they react to it. This performance decrement is exacerbated in cognitively demanding situations such as driving (Kemp, 1973). Once a decision has been made to react, reaction time itself is compromised with age (Stelmach and Nahom, 1992). UK drivers aged 70 and over displayed significant relationships between reaction time and serious driving errors and car control problems (Simms, 1993). Some situations do not lend themselves to good SSD, such as crest-vertical bends, which interfere with trajectory control because they reduce SSD, thus hiding the long-range visual information required to identify the course of the road and to anticipate future events (Rumar and Marsh, 1998) and facilitate appropriate lane-keeping (Summala, 1998). Hence signage is often used in an attempt to compensate for insufficient SSD.

Charlton (2004) found that advance warning signs in conjunction with plates posting an advisory speed for the bend work best for severe bends, but may not work as well in situations that present perceptual distractions, although severe bends often produce a reasonable amount of slowing by themselves. It has been suggested that the limited effectiveness of bend warning signs may be due to their over-use, particularly in lower-risk situations (Jorgensen and Wentzel-Larson, 1999).

Drivers' perceptions of speed and curvature seem to work at both conscious (explicit) and subconscious (implicit) levels. Consequently warning signs and road markings that highlight the sharpness of the bend ahead or increase drivers' sense of their own speed seem to assist in reducing the speed at which drivers enter bends (Charlton, 2007). These road markings may also help drivers choose and maintain appropriate lane positioning through the bend. Combinations of warning signs and road markings may be particularly beneficial for older drivers, as perceptual cues would be presented in different ways thus reaching them throughout the process of information assimilation and processing in response to approaching a hazard, reducing the likelihood of information being missed or any delay in reacting to the information through inappropriate prioritisation of information.

Different types of warning signs are used in bends, and these have been shown to have different levels of effectiveness in different situations. Chevron boards produce greater reductions in approach and entry speeds than advance warning signs, particularly in relation to high-speed and moderate-speed bends (Charlton, 2004). Koorey *et al* (2002) suggested that chevron boards with advisory speeds may be more effective at focusing drivers' attention on the suggested speed due to their placement directly in drivers' line of sight. Older drivers' compliance with instructional road signs suggests that these may be particularly useful in providing them with easily digestible information to help them negotiate the bend. Charlton (2006) points out that interestingly, drivers' detection rates for both chevron boards and advance warning signs are quite low, with slight advantage for the warning signs with 29% detection rate compared with 10.5% for black-and-white chevrons and 22.5% for fluorescent orange-and-black chevrons. This suggests that the location of chevron signs does not offer greater conspicuity, but it has been hypothesised that the benefits of chevron boards lies in the unconscious (implicit) processing of perceptual information relating to the bend (Charlton, 2004), as the board acts as a warning sign and a delineation treatment highlighting the outer point of the bend and the sharpness of the bend in one. This may explain why they are a more efficient safety measure than warning signs (Zwahlen, 1987; Charlton, 2004).

Advance warning signs rely on explicit attentional processes, while chevron boards continue to provide reductions in entry speeds even when drivers are distracted by secondary tasks (Charlton, 2004). The distraction of a secondary task in a younger driver sample may be comparable to the effects of age-related cognitive processing deficits in an older driver, which suggests that chevron boards may be beneficial for the older driver group. Several studies have indicated that a series of repeated arrow markers were even more effective for speed reduction, minimising speed variability and reducing centreline encroachments compared with a single chevron board or standard edge marker posts (Gates *et al*, 2004; Herrstedt and Greibe, 2001).

The findings that repeater arrows were just as effective for the sharpest bends and nearly as effective at higher speed bends indicates that the ability to highlight the risk points of the bend perceptually is more important in moderating driver behaviour than providing advisory speeds. This is supported by Bhatnagar (1994) who argued that when negotiating sharp bends, drivers require information beyond that provided by signs. Repeated arrow markers around the outside edge of the bend meet that requirement by providing additional visual cues allowing drivers to accurately assess the sharpness of the bend (Zwahlen and Schnell, 1996). This combination of implicit and explicit perceptual information is likely to be particularly beneficial for older drivers as it provides a greater quantity of perceptual information thereby compensating for their propensity to suffer observational and perceptual errors and cognitive processing declines.

Vehicle-activated warning signs have been shown to reduce approach speeds at bends in rural locations (Preston and Schoenecker, 1999; Winnett and Wheeler, 2002). Reflective thermoplastic road markings including a directional arrow and the word “slow” prior to the curve have also shown benefits in terms of reduced entry speeds (Retting and Farmer, 1998). Road markings including transverse lines with decreased spacing prior to entry to the bend have also been shown to reduce approach speeds in some situations (Charlton, 2004; Vest *et al*, 2005) but these findings were not supported in other studies (Comte, 1998).

Continuous rumble strips placed on the edge-line and centre-line have been found to improve lane-keeping (Rasanen, 2005) and reduce the incidence of run-off-road crashes (Torbic *et al*, 2004). Rumble strip treatments displayed substantial effects on drivers' speeds, but the effects were the greatest in the later sections of the bends, which may be because only the drivers who drive on either the edge-line or centre-line as they negotiate the bend will be pushed onto the strips and experience the auditory feedback (Charlton, 2007). There were no instances of drivers over-reacting or swerving into the oncoming traffic as a result of encountering the rumble strips. The use of rumble strips may be beneficial for older drivers as there may be situations where their visual perception is compromised in a particularly dangerous location such as a sharp bend, through the position of the sun, variation in lighting conditions attributable to tree cover, glare from oncoming headlights emerging round the bend, etc., so rumble strips provide information through other senses i.e. the auditory feedback and the sensation of vibration. However there is also some evidence to suggest that older people find rumble strips particularly uncomfortable if they suffer from specific medical conditions.

Perceptual treatments appear to help drivers to compensate for absent perceptual information from the road geometry, and drivers are therefore able to control their trajectory more efficiently (Rosey *et al*, 2008). Older drivers may find that they are less able to assimilate perceptual information even where it exists, so the supplementary benefit of rumble strips might be particularly pertinent to them. The analysis of lateral position showed two main effects – rumble strips on both sides of the centre line and the edge-line are effective in pushing drivers to the centre of their lane, and the perceptual treatments had an effect on drivers' positioning before and/or after the treatment zone.

6. Passing zones and overtaking

Research on overtaking collisions is quite rare although the collisions themselves are not, and they are typically quite serious. In 1998-1992 they accounted for over 7.9% of fatal road accidents in Nottinghamshire, and their "accident severity index" (proportion of cases resulting in fatality/serious injury) is over 20% (Clarke *et al*, 1998). In the US, it has been reported that 1.4%-2.6% of all crashes on rural single-carriageway roads are related to overtaking, and the percentage of collisions resulting in fatal or incapacitating injuries is higher than that of non-overtaking collisions (FHWA, 1994). Given that older drivers are more vulnerable to death or serious injury when involved in a collision (Staplin *et al*, 2001) and overtaking collisions are typically more serious than other types of collision, they present a very high risk for older drivers. And whilst older drivers are generally less likely to carry out reckless high-speed overtaking manoeuvres, their increased cautiousness may mean that they are more likely to be viewed as an impeding vehicle by other road users and therefore be overtaken, making them part of the overtaking situation (and placing them at the increased risk associated with that situation) even though they did not initiate the overtake.

Overtaking manoeuvres require a series of complex information-processing and decision processes which makes them one of the most demanding and risky processes carried out by a driver (Khasnabis, 1986). Key issues include the sight distance needed (Polus *et al*, 2000; Brown and Hummer, 2000) which may be different for older drivers due to visual and cognitive differences compared with younger drivers, influence on the speed of both the overtaking and impeding vehicle on the number of passing manoeuvres carried out (Bar-Gera and Shinar, 2005), and the impact of impatience on critical gap (Pollatschek and Polus, 2005) which is relevant to older drivers in terms of being overtaken as well as overtaking. Wilson and Best (1982) identified several strategies used in overtaking manoeuvres on an English rural A-road. Examples included "flying overtakes" whereby drivers did not brake and follow the impeding vehicle prior to the overtake, "piggy-back overtakes" which involve following a preceding vehicle which overtakes an impeding vehicle, "multiple overtakes" i.e. overtaking more than one vehicle at a time, and "accelerative overtakes" where the overtaking vehicle is increasing in speed throughout the overtake. All the strategies were observed to employ small gaps which increased proximity to the impeding vehicle in two ways – "lane sharing" behaviour whereby the overtaking vehicle did not move fully across the centre line into the opposing carriageway during the overtake, and "cutting in" which involved the overtaking vehicle returning to their lane early and without sufficient distance from the vehicle they had overtaken. Wilson and Best concluded that any action increasing a driver's proximity to the impeding vehicle "increases geometrical risk".

The increased proximity of an overtaking vehicle to an impeding older driver is likely to increase their cognitive workload due to increased driver stress, thus increasing the risk of compromising decision making efficiency, reaction time and consequently vehicle control (Kemp, 1973). Clarke *et al* (1998) outlined nine types of overtaking collision – right turn, head-on, sideswipe, cut-in, lose control after, lose control during, junction, nearside overtake (undertake), and avoidance of another driver's overtaking error.

Drivers aged 56 and over tend to be involved in "right-turn" overtaking collisions when moving off, carrying out a U-turn, or overtaking into the path of a vehicle which is already overtaking them, indicating that observational errors contribute to their collisions. The vehicles overtaken by older drivers tend to be farm vehicles or HGVs, suggesting that older drivers do not have a tendency to overtake unless substantially impeded. Clarke *et al* reported that commonly the indicator on the right-turning vehicle is masked by the glare of sunlight, a particular problem for older drivers due to visual decrements (Schieber, 1994), and there is minimal involvement of excess speed among these drivers. Important differences between younger and older drivers' overtaking collisions involving right-turns were found – these collisions occurred because a young driver made an inappropriate overtake or an older driver made an inappropriate right-turn. In general, the tendency is for "right-turn" overtaking collisions to involve a lack of observation, while "head-on" collisions involve a combination of poor observation and lack of judgement, with drivers aged 75-81 (the oldest group in the study) over-represented in terms of collision frequency. The "lose control after" collision is characterised by bad judgement and excess speed, and is not characteristic of older drivers. The "cut-in" collision was found to be over-represented among older drivers compared with younger drivers, as were "avoidance of another driver's overtaking error". The avoidance-related collisions may happen to older drivers as they become more apprehensive and start taking more frequent and/or less appropriate actions to avoid the overtaking manoeuvres of other drivers. It may also be that their slower and more hesitant driving style leads to frustration among other drivers and encourages inappropriate overtakes, which then require the older driver to take avoiding action (Clarke *et al*, 1998). The "nearside overtake" collision was also associated with older drivers, and seem to be attributable to inattention and confusion relating to multi-lane road environments and junctions.

The capacity of a segment of single carriageway road depends heavily on the percentage of section length where overtaking is prohibited, as a slow vehicle will generate a queue and reduce the capacity of the road. Consequently a passing sight distance (PSD) sufficient for drivers to pass slow vehicles should be provided at regular intervals (Hassan *et al*, 1996). Gattis *et al* (1997) and Romana (1999) studied overtaking behaviour on single carriageway roads, and found the overtaking rates increase as the separation gap between overtaking and impeding vehicles falls below three seconds. If the proportion of long and/or slow vehicles in the traffic stream increases this will lead to gaps of less than 3 seconds and the number of vehicles attempting to overtake will increase (Hanley and Forkenbrock, 2005). Older drivers tend to drive more slowly to compensate for declines in visual and cognitive processing performance, especially in situations they perceive to be difficult, for example busy roads, roads with lots of bends, in the vicinity of junctions or merging areas (Schlag, 1993). Kaub (1990) reported that as opposing traffic flow increased from 285-425 vehicles per hour to 400-590 vehicles per hour, the number of attempted overtakes reduced by 76% on US roads. The mean overtaking time decreased by 7.4%, which implied that average speed increased, and the percentage of aborted overtakes increased from 0.8% to 7.0%. Under conditions of low opposing traffic, the number of flying passes will increase, but as opposing flow increases, more vehicles will need to decelerate and wait behind the impeding vehicle, which may in turn lead to more failed overtakes (Hanley and Forkenbrock, 2005).

The speed differential between the overtaking and impeding vehicles is higher in a flying overtake than in an overtake that requires the driver to wait behind the impeding vehicle prior to commencement of the overtaking manoeuvre. Speed differential is important because as it decreases, the time the overtaking vehicle is in the opposing carriageway increases, and greater exposure time increases the risk of a failed overtake or indeed a collision (Hanley and Forkenbrock, 2005). However, the reduced observational abilities and cognitive processing speed associated with older drivers means that when a vehicle overtakes them with a high speed differential, they may be less likely to be aware of the vehicle and be able to act accordingly. This increases the risk of the older driver pulling out into the path of the overtaking vehicle, or being unable to react in time to avoid a collision if the overtaking vehicle makes a mistake.

Sixty to eighty per cent of drivers have been found to overestimate the time to collision (Hoffman and Mortimer, 1994), with a key factor being drivers' inability to accurately judge the safety of an overtake as the gaps in the opposing traffic stream are reduced. Additionally, drivers of all ages have been found to misjudge the speed of the traffic they are following and the relative acceleration of their own vehicle, rather than the speed of the oncoming traffic (Clarke *et al*, 1998). Gordon and Mast (1968) investigated drivers' ability to judge the distance required for a successful overtake on a single carriageway, and compared drivers' estimates with actual overtaking distances. Key conclusions were that drivers were unable to accurately estimate overtaking distances, errors of estimation increased as speed increased, greater distances were required as the speed of the impeding vehicle increased, and differences between vehicles affected overtaking distance to a greater extent than differences between drivers, indicating that this is no more of a problem for older drivers than any other driver group.

As vehicle length increases, the speed of overtaking vehicles also needs to increase if an overtaking manoeuvre is to take place within a similar gap in the opposing traffic compared with an overtake on a car. If overtaking speed does not increase, the driver would either have to wait behind the impeding vehicle until a much larger gap in the opposing traffic stream appears, or accept an effectively smaller gap than they would to overtake a car. If drivers choose to wait for a large gap, it is likely that congestion on the road will increase (Hanley and Forkenbrock, 2005). Increased congestion is also a product of prohibiting overtaking on sections of road, but the safety benefits in the prohibition section are significant. Summala (1980) found that it reduced the number of collisions directly involving overtaking, and also increased following distances and distance from the centre line, as drivers are not positioning for possible overtakes. However, it is possible that once a non-prohibited zone is reached, safety benefits reduce considerably as frustration provokes a greater number of drivers to attempt to make more overtakes in a short length of carriageway, under more congested conditions.

Drivers have been found to show little or no reduction in speed in conditions of reduced visibility caused by road geometry, which contributes to the significant numbers of overtaking collisions occurring in close proximity to bends, dips in the road and hill crests (Clarke *et al*, 1998).

Hills (1980) attributes drivers' acceptance of risky overtaking behaviour in these situations to the high probability that there will not be an obstruction or opposing vehicle, which leads to driver expectancy that they will “get away with it”. Fuller (1992) refers to this phenomenon as “learned riskiness”. At locations with good visibility, drivers can utilise cues from the traffic and road environment, along with road markings, to determine the most appropriate time for overtaking manoeuvres (Charlton, 2007b). However, some drivers use good visibility as a justification for making inappropriate overtakes. Harris *et al* (1986) observed video of overtaking manoeuvres and found that HGV drivers were particularly likely to use right-turn filter lanes as overtaking lanes.

Overtaking lanes are often built in to rural roads on the basis that they improve safety by providing an opportunity to overtake safely, although surveys have identified considerable problems with understanding overtaking lanes’ signage and road markings, and with compliance with the rules of overtaking lane use (Mutabazi, Russell and Stokes, 1998). Older drivers tend to have more problems with comprehension of the traffic environment compared with younger drivers, so this misunderstanding is likely to present more of a problem for the older driver group. Research has been conducted into the length, spacing and geometry of overtaking lanes, based on quantitative models, simulations and willingness-to-pay considerations (AASHTO, 1994; Hassan, Abd El Halim and Easa, 1998; Koorey and Gu, 2002). Although three-lane roads with alternating overtaking-lane priority can be beneficial for road safety in some situations, they have also been found to produce shorter headway distances and generally lower safety margins (Summala, 1980), and the layout can be inadequate in the light of actual vehicle speeds and driver behaviour (Lerner *et al*, 2000).

Trials of overtaking lane entry (diverge) road markings found that painted continuity lines can increase the number of vehicles remaining in the main lane and also the number of overtakes *per se*ction of overtaking lane (May, 1991). The use of continuity lines is consistent with the SER perspective and therefore may mitigate some of the risk associated with older driver confusion in relation to overtaking lanes by encourageing them to keep in their lane. However, older drivers’ uncertainty in relation to diverge and merge areas (Schlag, 1993) indicates that there may be increases in their stress levels that may compromise their driving abilities in such situations.

7. Roadworks

In roadwork zones in the US, around 700 fatal collisions happen every year, as well as 24,000 non-fatal injury collisions, and 52,000 damage-only collisions (Khattak *et al*, 2002). Research has shown that collision rates in highway construction zones are higher than in non-work zones (Garber and Zhao, 2002; Pal and Sinha, 1996). Crash rates have been found to increase approximately twofold in roadwork zones compared with crash rates in preceding years on the same stretch of road (Pigman and Agent, 1990).

Li and Bai reported that fatal collisions in roadwork zones were most likely to be caused by drivers over 64 and those between 35 and 44, but did not specify whether the older drivers were likely to be the fatality in the collision, which would mean that the statistics may reflect the frailty of the driver rather than necessarily the severity of the collision. Older drivers were not found to cause many injury crashes. Li and Bai identified key causal factors of roadwork-zone collisions as disregarding of traffic control, alcohol use, speeding, unfavourable light conditions and complicated road geometry. The first three factors do not typify the behaviour of the older driver group, but the last two factors are likely to have a more significant impact on older driver risk than that of younger drivers, due to visual decrements, cognitive declines and lack of confidence in unfamiliar driving conditions associated with older drivers.

Findings relating to roadwork zone duration and crash risk are mixed – Khattak *et al* (2002) reported that crash frequency increased with work-zone duration, and concluded that by reducing the length of time a roadwork zone is in place, rates of injury and non-injury collisions can be reduced. It has been suggested that in long-term construction zones, considerable collision rates can be expected (Rouphail *et al*, 1988; Ullman and Krammes, 1990), although Rouphail's findings indicated that whilst crashes increased in absolute terms in long-term work zones, crashes per mile/day increased from 0 to 0.219 in long term zones and 0 to 0.8 crashes per mile/day in short term zones, suggesting that drivers become accustomed to driving in long-term work zones and safety is thereby increased. Having said that, the protective effect was restricted to fatal and injury crashes (20% decrease) as the rate of non-injury rear-end collisions increased by nearly 50%. This effect may be particularly important for reducing older drivers' risk of fatal or injury collision involvement in a roadwork zone, as familiarity with a traffic environment has been found to be a key factor in minimising driver stress (Gandolfi, 2010) and consequently maximising driving performance for the older driver group. However, older drivers are much more prone to rear-end collisions and therefore the higher frequency of this kind of collision places them at increased risk.

In terms of collision severity, there have been mixed findings about whether collisions occurring in roadwork zones are more or less serious than those occurring at other points of the road network (Li and Bai, 2008). Ha and Nemeth (1995) found that crashes in roadwork zones were slightly less severe than other crashes, while some statistics have implied that roadwork zones in particular locations are especially dangerous, such as in rural areas, where in the US they were found to account for 69% of all fatal collisions on comparable roads (AASHTO, 1987). The severity of a collision can be measured using the crash severity index, a scale ranging from 0 to 1 which identifies the likelihood of a collision being serious enough to involve fatalities. In roadwork zones, one of the highest crash-severity profiles identified in Li and Bai's (2008b) study (0.62) involves a driver aged 65 or over, driving during the day (between 10am and 4pm) in good light conditions on a straight and level dual carriageway road with a speed limit of 60mph. This indicates that older drivers may be particularly at risk in areas of highway construction, possible due to unfamiliar information and confusing road layouts which increase cognitive workload and exacerbate cognitive declines and the impact on driving performance.

It has been suggested that as construction activity increases in a roadwork zone, the number of collisions will also increase (Sorock *et al*, 1996). Ullman *et al* (2006) also identified that the number of crashes increased significantly during periods of activity in the roadwork zone compared with inactive periods. Garber and Zhao (2002) analysed the different areas of roadwork zones in Virginia between 1996 and 1999 – advanced warning area, transition area, buffer area, activity area and termination area. They found that the activity area was the main location in which collisions occurred, and the majority were rear-end crashes – the crash type identified as most prevalent (29%) in roadwork zones by Pigman and Agent (1990), followed by sideswipe collisions (14%). Pigman and Agent identified driver distraction/inattention in the roadwork zone (32%), failure to yield right-of-way (15%), insufficient headway (12%), and excess speed (10%) as key contributors to collisions.

Older drivers are particularly at risk of rear-end collisions (Gandolfi, 2010), and the increased propensity for rear-end collisions to occur in roadwork areas (31% of crashes in roadwork zones, 17% outside – Sorock *et al*, 1996) suggests that drivers of all ages are falling victim to the circumstances that provoke rear-end collisions – insufficient headway, poor forward observation, driver distraction, misjudgement (Chambless *et al*, 2002; Daniel *et al*, 2000) – and so the risk for older drivers is further increased as the nature of the roadwork environment lends itself to these problems, to which they are already vulnerable.

Findings related to perceived hazardousness of the roadwork environment are mixed – Benekohal *et al* (1995) surveyed HGV drivers and found that 90% felt that driving through roadworks was more hazardous than driving through non-work zones, while earlier research of general motorists had found that 58% had reported that driving through roadworks was hazardous (Benekohal *et al*, 1993). 77.5% reported paying more attention to warning signs in roadwork zones, and 97% thought that speed limits were posted correctly but the research did not ascertain whether they chose to adhere to the speed limit. Drivers' perception of the risk associated with a traffic environment is likely to impact on their behaviour when negotiating that situation. In younger drivers, a high risk perception is likely to lead to more cautious behaviour and improve safety, but in older drivers it may have a negative effect as nervousness causes increased cognitive workload and in turn affects observation, information processing, prioritisation and decision making.

Sorock *et al* carried out analysis of roadwork zone collisions and found that pre-crash activities could be allocated as stopping (25%), making a driving error (12%), merging (5%) and cutting off another driver (4%). Crash types displayed a slightly different distribution than anticipated based on other studies – side impact (30%), rear-end (20%), hit large object (8%), hit small object (2%) and overturn (2%). This still indicates that rear-end collisions constitute a significant proportion of collisions in roadwork zones, highlighting the risk for older drivers especially given their propensity to increased driving errors and their hesitancy in merging with other traffic. However, the most common types of fatal collision in roadwork zones have been found to be head-on collisions (Daniel *et al*, 2000; Li and Bai, 2008), although disagreement exists over the fatality levels for other collision types. Daniel *et al* (2000) identified single-vehicle collisions as a key type of fatal collisions, while Li and Bai highlighted multi-vehicle accidents for both fatal and injury collisions.

Li and Bai reported that rear-end collisions were the dominant injury collision type, followed by side-impact and fixed-object crashes. The dominance of rear-end collisions was attributed to high speed and close following, and places where older were drivers at increased risk through age-related decrements in reaction time.

Collisions in roadwork zones often occur during the day and in the summer months when road construction projects are most common (Mohan and Gautam, 2002; Chambless *et al*, 2002; Hill, 2003; Li and Bai, 2006). Adverse environmental and road surface conditions did not contribute more to collisions in roadwork zones than to collisions in non-work zones (Garber and Woo, 1990). Time of day and weather conditions are not key factors in roadwork-zone crash risk, although poor light conditions were associated with a considerably greater proportion of fatal collisions (47%) than injury collisions (25%) (Li and Bai, 2008). Collisions occurring in roadwork zones at night were found to be much more serious than those occurring during daylight hours (Garber and Zhao, 2002). Ullman *et al* (2006) reported that the potential for high numbers of crashes during workzone activity was greater at night than during the day. Older drivers tend to display less tendency to drive at night with increasing age (Gandolfi, 2010), so they should not be excessively vulnerable to the increased night-time crash risk.

One of the key factors to be considered in choosing whether to undertake night-time roadworks is the safety of both the road users and the workforce (Arditi *et al*, 2007). There is limited data available comparing the characteristics of the collisions occurring during the day and at night in roadwork zones (Birch, 1998), but key concerns relate to reduced visibility, increased traffic speeds, and increased frequency of impaired drivers through alcohol use or fatigue (Arditi *et al*, 2007). The prevalence of night-time roadworks is increasing (McCall, 1999) due to the benefits such as minimising daytime congestion, increasing productivity through reduced interference, safer work practices due to less exposure to road users, and faster delivery cycles if a day and night shift are operating on the site (Arditi *et al*, 2007).

Statistics indicate that night-time roadworks are approximately five times as dangerous as daytime ones, but this finding is only in relation to fatal collisions and does not consider the risk of injury and property-damage collisions (Arditi *et al*, 2007). Li and Bai report that daytime non-peak hours (10am-4pm) displayed the highest frequency of injury collisions (42%) and the second highest level of fatal collisions (32%). Thirty-seven per cent of the fatal collisions happened between 8pm and 6am, 19% more than injury crashes in the same time period (18%). Some of the danger to the workforce of night-time roadworks can be offset by rigorously ensuring that safety practices are adhered to, such as the use of safe construction methods, adequate lighting, and adequate safety wear. Jin *et al* (2008) found that strong compliance with safety recommendations can be cited as the key contributing factor to the finding in their study that no significant differences in crash rates existed between construction and non-construction time.

The benefits of temporary road markings and road signs in roadwork zones are considerable, but it must be clear to the road user which markings and signs are meant for the duration of the roadworks and which are the original ones from the previous road layout. Older driver confusion can be a significant contributor to their collisions, therefore ambiguity of signage must be avoided.

One road marking used to reduce speeds in roadwork zones is optical speed bars – transverse stripes at gradually decreasing intervals to affect drivers' speed perception and make them feel they are travelling faster than they actually are. Meyer (2004) reported that speed bars have a warning effect and a perceptual effect, and were effective for speed reduction and minimising speed variability. Benekohal *et al* (1995) reported that half of HGV drivers wanted to see warning signs three to five miles prior to the roadwork zone. Garber and Woo (1990) found that traffic signs could reduce work zone crashes when used with who are workers that direct traffic. Flaggers are suitable for short-duration works (i.e. up to 1 day) and for intermittent use in long-term roadwork zones (Richards and Dudek, 1986). Garber and Woo (1990) reported that flaggers enhance the effectiveness of a system of traffic cones and static signs, and Li and Bai (2009) stated that the presence of a flagger directing traffic can reduce the chance of having a fatal crash by 56%, as they seem to focus drivers' attention and minimise the risk of human errors categorised as “disregarded traffic control”, “inattentive driving”, and “driving too fast for conditions”. However, Benekohal *et al* (1995) indicated that flagging needed to be improved and/or regulated, as a third of HGV drivers indicated that flaggers were often hard to see, and half considered their directions to be confusing. Visibility and potential confusion are quite serious issues for older drivers, but these findings may not be replicated with car drivers as there may be characteristics of HGV driving that exacerbate the problem, i.e. the height of the driver in the HGV cab relative to the position of the flagger, tendency for HGV drivers to drive internationally leading to possible national differences and lack of comprehension. Older drivers are unlikely to have these problems.

Traffic engineers base their faith in temporary traffic control devices to improve safety in roadworks zones on the devices being designed, installed and maintained properly, but the extent to which they have improved safety is unclear (Li and Bai, 2009), as there is no evidence of temporary traffic control use effectiveness in reducing crash severity, no straightforward measure of the effectiveness of individual temporary traffic controls, and no research into their use with older drivers. It is suggested that temporary traffic control signals (TTCSs) should be used with other devices such as warning signs, regulation signs, road markings and channelizing devices. Some TTCSs, such as stop/go signals, have been shown to be effective in reducing fatalities in roadwork zones (Hill, 2003).

Portable changeable message signs have been shown to be more effective than traditional signs in reducing the number of speeding drivers in roadwork zones (Garber and Patel, 1994; Garber and Srinivasan, 1998), but Richards and Dudek (1986) reported that changeable message signs lose their impact when operated continuously displaying the same message for extended time periods. Some studies have found that flashing warning lights, especially those associated with police vehicles, were one of the most effective means of reducing speeds in roadwork zones (Huebschman *et al*, 2003; Arnold, 2003).

Pain *et al* (1993) reported that most channelising devices used in roadwork zones were effective in alerting drivers to hazards and guiding them through the roadworks, but the devices only achieved full effect when deployed as part of a cohesive system of devices.

Garber and Woo (1990) found that using barricades was effective but their use in conjunction with traffic control devices reduced the effectiveness of the devices, but the large percentage of head-on collisions occurring in roadwork zones indicates that median separators are required (Li and Bai, 2008). Li and Bai (2009) reported that having flashers or centre/edge lines in roadwork zone could have a substantial impact on driver behaviour and reduce the chance of a fatal crash by over 50%. For older drivers, the key issues in roadwork zones are that they are clearly and visibly informed of the appropriate path, speed and driving behaviour required to safely negotiate the work zone. The main risk is that they will be confused by the combination of signage and road markings from the original road layout and the active work zone, and that it will lead to cognitive overload, decision making errors and compromised driving performance. It is as yet unclear which forms of signage and channelling devices are most appropriate for older drivers in a roadwork zone.

8. Coaching Interventions

Good driver coaching and training interventions have long been found to bring safety improvements, particularly by local authorities. For example, interventions to enhance hazard awareness enable drivers to spot hazards more quickly – and we know that speed of hazard perception is related to reduced crash risk (Wallis and Horswill, 2007).

As recent research shows that on-road driving experience brings better hazard perception and cognitive-based driving performance (Borowsky, Oron-Gilad and Parmet, 2009) it seems reasonable to assume that a bespoke driving course for older drivers could aim to sustain experience-based perceptual / awareness skills. Similarly, speed awareness courses have made noticeable improvements to people's driving behaviours; this may illustrate another area where older driver interventions could provide benefit, as speed is another key factor in age-related driver involvement in intersection accidents (Spek, Wieringa and Janssen, 2006). Additionally, coaching interventions could be used to raise general understanding and self awareness of capabilities as recommended by the OECD (OECD, 2001). For example, older drivers tend to underestimate oncoming vehicle speed and make unsafe judgements about oncoming traffic gaps (Oxley, Fildes, Corben and Langford, 2006) despite the fact that they need more time to make decisions about turning (Caird, Edwards, Creaser and Horrey, 2002) and accelerating (Hakamies-Blomqvist, 1996). Overall then, various research findings suggest many potential areas in which interventions could be developed to assist older drivers. Participation on such programmes would also induce greater confidence as an additional benefit.

9. Car Design

Research indicates that even after giving up the car a large proportion of drivers would still prefer to get around by car, suggesting that the car will remain an important means of transport for people in their later years (Brace, Elliman, Page, Rackliff, Welsh and Morris, 2006). A major report on 'Ageing and Transport' published by the Organisation for Economic Co-operation and Development in 2001 proposed that older drivers needed not only to be informed about the implications of their age-related impairments and driving cessation, but also about choices of safer vehicles (OECD, 2001). To improve the safety of older drivers and to help them feel more confident to remain independently mobile it will be important to make sure that their vehicles not only contain the appropriate features but that the users will be adequately informed about them.

9.1 Intelligent Systems

As technology continues to advance we will inevitably see further development of in-car technology and intelligent systems designed to override human weaknesses in driving. To date, a considerable amount of research has already explored the efficiency and effectiveness of developing vehicle safety capabilities. For example, one recent study found that warning systems activated by vehicle interface technologies were effective whereas, in contrast, warning systems activated by the immediate road infrastructure were not (Neale, Perez, Lee and Doerzaph, 2007). However, the results of general studies may have little specific relevance to the older driver population and rigorous independent testing needs to be undertaken to evaluate the utility and effectiveness of each technological development for older age groups.

Age-related cognitive decrements reduce attention, memory and reaction time performance abilities that cause drivers to experience a heightened sense of workload demand (Dingus, Hulse, Mollenhauer, Fleischman, McGehee, and Manakkal, 1997). As we age, we also become more easily distracted and less able to utilise complex information and usefully discern competing sources of information (Holland, 2001). This is why the adoption of new technology becomes increasingly more difficult for older people and why older drivers find that additional functions and technology can cause confusion and reduced decision making capabilities (Blanco, Biever, Gallagher and Dingus, 2006).

If we are to sustain mobility for older drivers this is an area of future research where additional work is needed. The development of intelligent and active safety systems should not be implemented in new cars *per se* unless sufficient research has been undertaken to establish that it is not going to further impede older drivers' confidence and capability. For example, will emerging 'smart' intersection devices assist the older driver or serve to add even greater cognitive workload to this already critical traffic situation? In-depth research to establish more conclusively what technological advancements are conducive to older driver safety would be of benefit not only to the drivers themselves, but also to road safety organisations and of course the car manufacturers who need to appeal to an increasingly aged market sector.

9.2 Ergonomic design

An additional consideration may be the consistencies of design standards between different car manufacturers and various vehicle models. Little empirical research has been found in the public domain which examines how internal features may assist older drivers and alleviate the problems of reduced mobility and visibility which have been long known. Although ergonomic considerations are now part of the car design process it remains the case that decisions are typically undertaken and tested by designers and engineers within the industry, and that there has been a relative paucity of empirical and independent research conducted (Fletcher, 2005). Moreover, as all drivers come to experience, there is little consistency in design across cars in terms of internal features – sometimes we simply have different personal preferences but it can be that some specific features and functions can reduce our capabilities. For older drivers it is likely that some basic functions might benefit from age-related research and adaptation. For example, in one recent US study it was found that older drivers involved in intersection crashes were unable to adequately operate the acceleration capabilities of the cars they were driving.

It is therefore reasonable to assume that car designers still lack a full understanding of not only general comfort preferences but also the full ergonomic consequences of design options. Comfort often lacks the same consideration paid to technical design as it is a less tangible 'qualitative facet of ergonomics' (Hanson, Weinholt and Sperling, 2003). However, the concept of comfort relates to psychological, physical, sociological and technological issues (Dumur, Barnard and Boy, 2004) and comfort impairments have been implicated as a factor in road accidents and incidents (Burger, Smith, Queen and Slack, 1977). Enhancing comfort would therefore not only encourage older drivers to remain mobile but would also help alleviate some of the physical and cognitive demands that can impair their driving capability.

More in-depth research to examine specifically how individual car design and internal features may assist older drivers when negotiating types of road infrastructure would be a valuable exercise.

9.3 Headlights and glare

Glare from oncoming traffic headlights is a major contributing factor to visibility-related driving difficulties (which can persist for some time after being experienced). Much research has already been conducted to investigate the effects of glare and establish preferable headlight design to help drivers e.g. direction, height, alignment etc. However, as any driver on today's roads will appreciate, headlight beams still vary considerably across different cars in strength, type, alignment, direction, etc. For example, recent US researchers who tested several hundred vehicles found that two-thirds had at least one headlight that was out of alignment, either aiming too low or too high (Bullough, Skinner, Pysar, Radetsky, Smith, and Rea, 2008). This means that vulnerable drivers may be suddenly faced with an 'abnormal' oncoming beam that could cause them unexpected physical and psychological difficulties. There may then be a very reasonable call to be made for governing and oversight agencies to implement more appropriate and consistent standards across the industry – from vehicle manufacturers to maintenance and enforcement organisations. Such standardisation could play a significant part in assisting older drivers and keeping our ageing population mobile. It would be relatively straightforward to conduct research and development work to establish what individual standards should be. However, research needs to be combined and integrated so that various important aspects can be taken into account. For example, whilst we know that reducing headlight beam strength will help reduce glare effects, we also need to make sure headlights are sufficient to optimise the luminance of road markings for older drivers (Graham, Harrold and King, 1996). Thus, research needs to be in-depth and comprehensive enough to establish a more finite optimal range of standards that balances different requirements – e.g. in this case, balancing needs for sufficient luminance with those for glare minimisation.

One example of developmental preliminary research is a US study conducted to investigate the advantages and disadvantages of high-intensity discharge (HID) headlamps or directionally adaptive headlamps. The study surveyed drivers to assess experiences of the newly-adopted technologies with drivers without them, and to determine *"the extent to which glare from other drivers' headlamps may be a problem for drivers equipped with HID and non-HID headlamps"* (Jenness, Lerner, Mazor, Scott Osberg and Tefft, 2008, p.7). The authors recommend: "[F]urther objective research is needed to determine if and how HID headlamps may be beneficial for improving visibility for older drivers" (Jenness, Lerner, Mazor, Scott Osberg and Tefft, 2008, p.58).

Although the accident liability of older drivers may be inflated as a result of older drivers tending to drive shorter distances (Langford, Fitzharris, Newstead, & Koppel, 2004), it is still worth considering how best to make them more comfortable and confident on these shorter, regulated routes. To this end, it may also be possible to explore ways in which older drivers are able to manage the impact of oncoming headlight glare using some type of internal protection device that dims the beam, without compromising overall visibility.

9.4 Impact reduction

It is reasonable to assume and expect that impact reduction is always a primary consideration and is optimised in the design of our vehicles. However, it may be that there are specific considerations that could be examined in relation to the needs of older people either as drivers or passengers. UK-based accident analysis research has reinforced that older drivers' skeletal structures significantly reduces impact tolerance, with chest injuries being a particular vulnerability (Welsh, Morris, Hassan and Charlton, 2006, p.323). Welsh *et al*, also highlight that older people have misconceptions about in-vehicle safety features which could be a significant cause of raised anxiety leading to on-road errors and driving cessation decisions. Moreover, research has generally neglected to consider wider 'socio-ecological' issues such as point of crash impact and relevance of time of day etc. (Awadzi *et al*, 2008). Thus, if further research and development led to greater impact reduction devices this would improve safety and older driver mobility.

10. Conclusions

The overarching finding from this review is that there are key older-driver issues which are consistently problematic in a wide variety of traffic situations, i.e. visual problems, cognitive processing speed, cognitive overload, perceptual errors/confusion, mobility issues, frailty, etc. These factors have an impact on older driver risk in each of the areas investigated. This raises a rather fundamental question – is it practical to attempt to adapt the traffic environment to meet the needs of the older driver, or should the focus be on trying to equip the older driver to deal with the existing traffic environment more efficiently? It is likely that the optimal solution would involve both approaches, as improvements to road infrastructure that would benefit older drivers are expected to, in many cases, benefit all drivers, thus improving their cost-effectiveness and adding weight to the argument for their implementation.

The research has highlighted some important factors which impact on older driver risk in each of the road environments studied, despite there being very little research relating directly to older drivers in any area except intersections. However, the research on these areas that referred to the general driving population, in combination with the well-established “older driver syndrome”, facilitated extrapolation of the particular risks facing older drivers and the identification of potentially effective countermeasures.

In terms of older drivers’ crash risk at intersections and junctions, it appears that performance may be improved by providing clearer, unambiguous signals, implementing alternative lower-risk traffic control devices (such as roundabouts) at risky junctions, reducing traffic speed on priority roads approaching high-risk junctions, and, indeed, implementing education strategies targeting both the older drivers and younger road users, as it seems that younger drivers are often unsympathetic to the driving style of older drivers and can go so far as to provoke collisions in which the older driver is deemed to be at fault.

The literature about roadway curvature displayed conflict in relation to the risk associated with increased bend frequency – some studies reported a protective effect, while others did not, or found it to be restricted to certain environments such as urban areas. There was no evidence to directly identify the effects of road curvature on older drivers, but general findings suggest that older drivers are at far greater risk at junctions than on roads with high bend frequency, as their main risk area involves dealing with other traffic. However, certain types of bend, such as very sharp bends requiring a significant speed reduction, or those that do not offer clear perceptual information, are likely to present a risk to older drivers, although the comparative risk of older and younger drivers in those situations remains unclear. It appears that all drivers would benefit from additional perceptual cues, and some studies suggest that older drivers benefit the most from advance warning signs, advisory speed limits and chevron markers – interventions that would provide useful information and risk-reduction benefits to all drivers.

In terms of overtaking, clarity of view and clearly interpretable road markings and signage were found to be the most appropriate interventions to help older drivers improve safety during overtakes, whether they were the overtaking or overtaken vehicle. It would be strongly advisable to implement education for older drivers to ensure that they are fully aware of traffic laws relating to overtaking, and to the meaning of signs and road markings, as well as to provide skills for dealing with difficult overtaking situations such as failed overtakes both on their part and by other drivers.

Roadwork zones present a high-risk situation for all drivers, but for older drivers it seems even more important to ensure that there is appropriate advance warning of entry to a work zone, followed by clearly visible and interpretable path guidance through the zone. Encourageing all drivers to maintain a greater headway between vehicles would also reduce older driver risk, as they are at greater risk of rear-end crashes than other drivers, and rear-end crashes are prevalent in work zones among the younger driving population, thus increasing older driver risk further.

The risks associated with level crossings are the same for all road users, but the age-related declines associated with older drivers increase their propensity to fall victim to these risks resulting in a serious incident. Lack of visibility is a key issue for older drivers, and poor comprehension of the nature of the crossing (and the appropriate way to deal with it) has also been demonstrated to be a problem. Increased clarity relating to the type of crossing (i.e. active/passive, mode awareness) would benefit all road users, as would speed reduction on approach to level crossings.

The lack of explicit older-driver research in these areas has resulted in this research relying heavily on extrapolation from general driver research using established knowledge on older driver risk. Consequently it raises an enormous number of new research questions, and begs for further study to confirm or refute the suppositions made on the basis of the non-older-driver-specific research. This provides a wide variety of options for future research, in a field which is becoming increasingly relevant with an ageing population.

11. Recommendations for future research

11.1 Specific research questions identified from the literature

As described in the previous sections, the literature has put forward various explanations and suggestions for countermeasures to address observational and perceptual problems older drivers face in relation to road infrastructure. There appears to be little that a road environment can do to counter many of the effects of age-related cognitive processing. However, 14 key problems emerged from the review which have not yet been explained by existing research to a sufficient extent to provide suggestions for appropriate countermeasures. These problems comprise a series of key questions, as set out below.

Q1. Older drivers' tendency to change lanes and emerge inappropriately into traffic streams at T-junctions, driveways and other entrances – is the key contributory factor observation, perception, cognitive problems, vehicle control problems, or is there no single overarching cause? What changes could be made to reduce their propensity to display this behaviour?

Q2. Right-angle collisions from the priority road when proceeding straight ahead at a crossroads – again, is there a key causal factor? What countermeasures could be implemented?

Q3. Slower turning acceleration when younger drivers are approaching more quickly – is it a perceptual problem relating to judgment of other drivers' approach speed, or a cognitive processing or motor skills issue? Could perceptual assistance combat this problem?

Q4. High frequency of bends and junctions – protective or threatening for older drivers? Is there a difference in this effect between urban and rural road environments?

Q5. Inappropriate lane positioning through bends – what are the main causes among older drivers, and the most effective countermeasures?

Q6. Over-prioritisation of accuracy over speed – is there anything that can be done to assist older drivers to prioritise information and process it more efficiently in traffic situations?

Q7. "Right-turn" collisions when moving off or overtaking – is this driven by the same processes as inappropriate pulling out at T-junctions and/or crossroads?

Q8. "Cut-in" collisions and "avoidance of another driver's overtaking error" – what causes over-reaction in older drivers, and what may reduce this effect?

Q9. The requirement for increased overtaking zone length – observational, perceptual or based in confidence? What countermeasures may assist in reducing the required distance?

Q10. Issues gauging the length of an impeding vehicle when overtaking (and consequently gap required) – is this problem related to observation, perception or cognitive processing? Is it a contributor to the requirement for increased zone length, or a separate mechanism? Could the same countermeasures address both?

Q11. Familiarity of message signs – is under-familiarity or over-familiarity more of a problem for older drivers? What is the optimal sign frequency on approach to a hazard? What impact does familiarity have on observation/perception, and does it interact with prioritisation of information and speed of processing?

Q12. Would the replacement of junctions with roundabouts show a tangible reduction in collisions in the UK? Are there differences between urban and rural environments?

Q13. How could level crossings be treated to maximise older driver awareness of the existence of the crossing, the type of protection it provides, and (for active crossings) the current mode of the crossing?

Q14. What are the most appropriate means of channelisation, speed management and headway maintenance for older drivers in roadwork zones?

11.2 Research recommendations

In this section we set out recommendations for research to explore a range of issues concerning older drivers and road infrastructure. Specifically, we first put forward 14 key questions (above) that are not yet adequately covered by previous research. Next we will set out suggestions for studies that may be conducted to address the emergent issues concerning UK infrastructure risk, infrastructure effectiveness, and impairments effects. Finally, we present additional ideas for further research and development projects derived from the literature and anticipated results.

Study to explore emergent problems

Firstly, we recommend that all of the 14 key questions above need to be explored by further research, as they are clearly important and not currently covered by existing literature. This could be done by using a combined approach involving analysis of the STATS19 data combined with in-depth interviews with older drivers.

A series of in-depth interviews would provide rich data on older drivers' views and experiences that could then be used to create relevant questionnaires. Then, with valid and reliable questionnaires it would be possible to survey a very large sample of the population to get a stronger understanding of all manner of issues important to older drivers in the UK. This would satisfy the need for a comprehensive picture of the UK situation.

The STATS19 data would provide insight into the frequency of collisions involving the issues identified from the literature, the locations at which they take place, the other drivers and vehicle types that are also involved in multiple-vehicle crashes, and prevalence of night and daytime incidents (See: DfT, 2009 for initial work in this area).

High collision-frequency sites could then be analysed in an attempt to identify patterns of older driver collisions and key factors contributing to older driver risk at those locations, and suggest countermeasures that could be implemented and trialled. Historic STATS19 data could also be used to identify changes in older driver collision patterns at locations that have been subjected to various infrastructure changes, in order to assess the effectiveness of existing interventions. Key questions 1, 2, 3, 4, 7, 11, 12, 13 and 14 could utilise STATS19 data and would benefit from supplementary in-depth interviews with older drivers to explain and/or confirm findings from the analysis of the collision records.

To address the other remaining issues (key questions 5, 6, 8, 9, and 10) it would be necessary to adopt different approaches. Issue 5 would probably be best studied using a driving simulator, where variables can be rigorously controlled and the older drivers could be tested on a variety of abilities in the same experimental session. Hence older drivers with varying visual abilities, physical mobility, reaction time, etc. could be compared on a standardised drive, and variables relating to the drive could also be manipulated i.e. time of day, traffic density and speed, weather conditions and visibility, surface friction, etc. In the absence of a simulator it may be possible to gain some insight by interviewing older drivers about their confidence in negotiating bends, asking them to self-assess their performance in different conditions, and gathering information about any age-related declines by asking them to report on their physical health and eyesight and to carry out basic physical and cognitive tasks deemed to be representative of the driving task.

Issue 6 may be best approached from a pure cognitive psychology discipline – a review of cognitive changes in information processing among older people may provide insight into the optimal way to present information for assimilation and processing by an older person, which could then be translated into road infrastructure.

Issues 8, 9 and 10 could be investigated using interviews to obtain older drivers' self-reports of overtaking behaviour, confidence in overtaking situations (as the overtaking and impeding driver), and reports of near-misses. This data may provide an indication of the key issues fuelling older drivers' propensity to have problems with overtaking-related situations, and in turn some steps that could be taken to improve the way in which they deal with them. It could also allow differentiation between older drivers' reactions to different types of overtaking situation, and their views on the different elements of overtaking, i.e. vehicle length, passing sight distance, passing zone length, vehicle speeds (actual and relative), gap acceptance, etc.

Infrastructure risk study

A study to identify the primary UK road infrastructure issues that are problematic for older drivers, and their relative level of importance in terms of perceived risk and actual risk:

- STATS19 data could be used to identify common features of older-driver collision blackspots, and identify collision characteristics specific to those locations (See: DfT, 2009);
- Interviews could be carried out to find out which infrastructure elements are perceived most positively and most negatively by older drivers; and
- Questionnaires could be developed to survey older driver opinions on a wider scale.

Infrastructure effectiveness study

A study of the current state of UK infrastructure elements and road environments to measure their effectiveness in relation to older driver risk:

- Formal assessment on key UK infrastructure elements could be conducted e.g. adequacy and state of road markings, visibility, width and length of turnings, etc;
- Interviews / survey of road design engineers and associated subject matter experts;
- Review of historical data UK road design improvements and interventions to evaluate effectiveness and outcomes; and
- Review of reporting systems to identify potential weaknesses and improve processes.

Impairments effects study

A study to identify how UK infrastructure elements are associated with the key impairment areas of mobility, cognition and visual ability, both perceived and actual:

- STATS19 reports could be analysed for any reference to mobility, cognition or visual decrements, and potentially further details of selected collisions could be gathered either from involved parties, accident investigation reports, or insurance databases;
- Interviews could be carried out with drivers suffering from problems with mobility, cognition and/or visual ability to gauge their views about their contribution to older driver risk. Differences in perceived symptom severity and perceived risk could be analysed for group differences; and
- Questionnaires could be developed from the interview data to survey a broader sample of older drivers.

The findings from the studies proposed could be combined to identify and evaluate what is lacking in terms of older-driver-friendly infrastructure changes, and the differences between road types and traffic situations could be considered (i.e. urban/rural, lit/unlit, high/low traffic volume). In light of all the information and analysis detailed above, recommendations could be made for improvements that could directly improve road design in relation to older drivers' abilities and impairments. The findings of a piece of research incorporating these elements could then lead onto further supporting research.

Study of car design improvements

The findings of previous analyses, the literature review, and possibly some further interviews with older drivers would enable us to make recommendations for improvements that would directly improve car design in relation to older drivers' abilities and impairments in terms of the three key performance decrements associated with older drivers: mobility, cognitive processing and visual ability.

Study of driver-oriented interventions

Driver coaching could improve older drivers' confidence and update/refresh their driving skills and Highway Code knowledge and therefore the development and evaluation of a pilot scheme may be of benefit (Suffolk County Council's Grand Driver Project provided a strong framework to build on in this area). Education for other road users to raise awareness of the increasing number of older drivers on the UK road network, and to publicise the challenges faced by older drivers, may also be beneficial. Advertising may help to promote considerate driving, and inclusion of an older-driver-awareness element in the Driving Standard Agency (DSA) syllabus and initiatives such as the National Driver Improvement Scheme could improve courtesy and appropriate reaction to older drivers from other road users. Pilot implementation and evaluation could assess the potential effectiveness of such interventions.

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