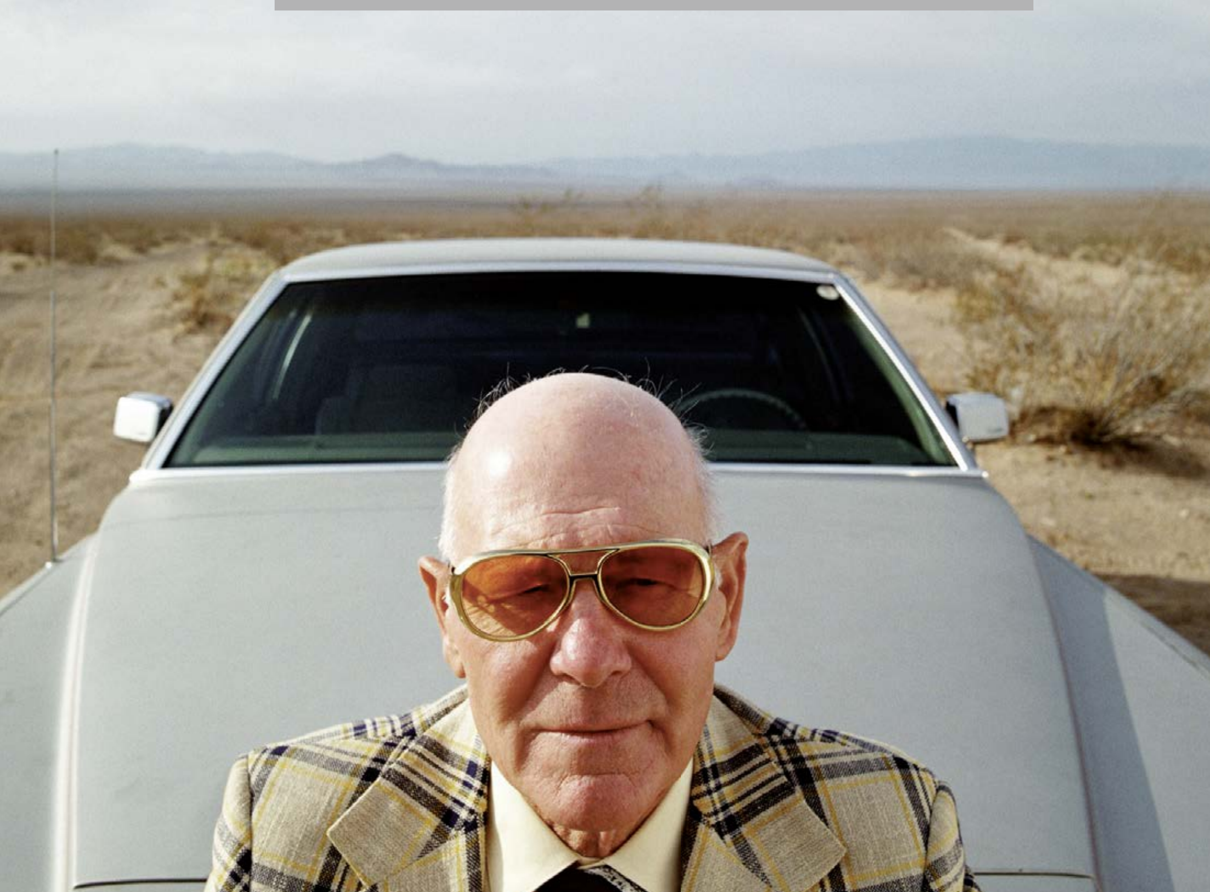
SaMERU
SAFER MOBILITY FOR ELDERLY ROAD USERS

Co-funded by the European Commission

EUGEN-OTTO-BUTZ-STIFTUNG

Accident patterns and prospects for maintaining the safety of older drivers

Gert Weller, Nora Strauzenberg, Margit Herle, Bernhard Schlag and Susann Richter



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Foreword

Every human being has a basic need for mobility. Whereas mobility demands can be a burden to many of today's young working people, it has a predominantly positive connotation in the everyday life of older people. Mobility makes it possible to meet individual needs, to participate in an active social life, and it is an important prerequisite for independence. However, it is paradoxically in old age that both the type and the scope of mobility become restricted. This restriction is a result of declining sensory, motor and cognitive abilities. Even though the demands on these resources vary between the different forms of mobility, all of them are negatively affected due to the overall number of age-related changes.

Of all the different forms of mobility, car driving is of particular interest in our society. The reasons for this are manifold. One likely important reason for this is that car accidents often not only affect the person causing the accident but also second parties. In addition, the media relishes reporting dramatic accidents where older people are at fault. This influences the perception of the risk associated with older drivers. However, car-driving is the most loved means of transportation for current and future generations of our aging population.

An alternative to taking away the driving license of older drivers is to ensure age-friendly auto-mobility by supporting the elderly through training and information and through implementing technical and design-based changes in cars and the driving environment. With this strategy, age-appropriate alternatives to driving only need to be discussed and be provided when car mobility can no longer be maintained.

This volume discusses the actual risk of driving in old age in terms of the topics outlined above. Furthermore, approaches and alternatives for age-friendly auto-mobility are discussed and their implementation is briefly outlined. These are illustrated using examples from selected European cities and communities.

This work originated from the EU-supported SaMERU project. The acronym SaMERU is short for "Safer Mobility for Elder Road Users" which perfectly describes the aim of the project. In this volume, selected results of the project are presented. SaMERU was a joint project of these partners:

- Southend on Sea Borough Council (Coordinator), England
- Atkins, England
- Ciudad de Burgos, Spain
- Comune di Modena, Italy
- Ifsttar (Institut français des sciences et technologies des transports, de l‘aménagement et des réseaux), France
- Lancashire County Council, England
- TU Dresden, Traffic and Transportation Psychology, Germany

We would like to thank all these partners and the European Union for their support!

Last but not least we would like to thank the Eugen-Otto-Butz-Foundation and Barbro Rönsch-Hasselhorn from the Research Department “Mensch-Verkehr” of the Eugen-Otto-Butz-Foundation for their support and for their ongoing and strong interest in the topic of elder people’s traffic safety. Their support not only facilitated but also enabled a large quantity of highly relevant publications in this research area and so contributed to improving elder people’s safety.

Dr. Gert Weller und Prof. Dr. Bernhard Schlag

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1 Introduction

In most OECD countries, seniors are currently the fastest growing demographic group and this trend is likely to continue for the next two or three decades. Forecasts suggest that by 2030, every fourth person will be older than 65 years (Schlag, 2008b). In OECD countries, it is expected that in 2050 more than a quarter of the population will be older than 65 years (OECD, 2012). In OECD countries the proportion of people over 80 years will rise from 4 % in 2010 to more than 10 % in 2050 (Colombo, Llena-Nozal, Mercier, & Tjadens, 2011).

In addition to the economic and financial effects from this demographic shift, there will also be a greater focus on transport safety for older people. The reason for this is the interaction between this demographic shift and increased mobility, especially in the demographic group of elderly drivers (Schlag, 2008b).

Thus, there is a strong need for political and social debate that is solution-oriented. The project "Safer Mobility for Elderly Road Users" (SaMERU) is intended to significantly contribute to this debate at the European level. Part of this project is to assess the risks to older transport users, based on scientific work and detailed analysis on accident figures.

One of the ways of describing transport safety is to use accident numbers. Often there is an increased risk of accidents involving elderly people. However, this increase is only seen from the age of 75 (Loughran, Seabury, & Zakaras, 2007). Currently, accident statistics do not take into consideration two influential factors, namely 'frailty bias' and 'low mileage bias'. This is despite the fact, that these can have great relevance to the assessment of accidents.

In order to analyse and assess the mobility of the elderly, it is important to take the following into consideration:

- demographic development and mobility development of the elderly,
- age-related changes as factors that influence mobility of the elderly,
- transport safety of the elderly, and
- solutions for safe mobility for the elderly.

However, during the SaMERU project there have been a number of issues relating to the analysis of accident data. Firstly, the word 'risk' is often used with different meanings including general risk, risk of injury, risk of death or probability of an accident. Secondly, accident statistics are not complete or the way they are handled varies from place to place, country to country. In Europe, for example, there are numerous years that cannot be compared because the number of EU member countries is different. The situation is aggravated by the fact that an unknown number of accidents are simply not reported and, thus, are not included in the statistics.

The age spectrum of seniors also requires a differentiated approach because they are a heterogeneous group. Many of the demands of road traffic that a 65-year-old can easily cope with represent a significant problem for many 80-year-olds or young seniors with health problems (Schlag, 2008b). Increased age results in various skills being subjected to age-related limitations. The skills required to drive a car are particularly susceptible to age-related changes such as alterations in perception, cognitive ability and psychomotricity. As well as age-related changes, a number of illnesses, and the medication taken for them, can influence mobility, in particular the driving ability of elderly people.

As part of the political and social debate, recommendations and possibilities for a safe form of mobility for elderly people are being discussed. It is important to keep in mind, that, generally speaking, driving in the elderly is positively correlated to quality of life, functional independence, and physical and spiritual well-being. As such, there should be a focus on maintaining the driving ability of elderly drivers through active training in simulators or real traffic; training for diminished body strength, agility and stamina; cognitive training; mobility advice; and road education (Ball, Edwards, & Ross, 2007; Ball, Edwards, Ross, & McGwin, 2010).

It is also highly recommended that communication be improved between doctors and patients in terms of mobility advice because doctors have an important role to play in assessing driving capability (Eby & Molnar, 2009). Another key factor of fostering the mobility of elderly people is sustainable town planning and transport planning that adequately takes into consideration the requirements and age limitations of this target group (see Chapter 3). This should include a number of various aspects. Accessibility, transport options and civil infrastructure should all be incorporated into planning. This report mainly discusses the structural measures which contribute to this goal.

2 Demographic change and its impact on traffic

2.1 Demographic change

The age structure of the population in the industrialised countries is projected to change greatly over the next four decades. Much of this change is driven by the aging baby boomers and trends in immigration.

The number of people older than 65 years is expected to double by 2050, an even higher increase is expected for people over 80 years within the same period (OECD, 2001b). By 2030, one out of every four individuals will be 65 years and older. In the OECD countries the proportion of older adults aged 80 years and older will increase from 4 % to 12 % (OECD, 2001b). It is expected that the age group 65+ will be the largest population in 2050.

In the USA the number of Americans aged 65 years and older is projected to be 72 million by the year 2030 and 11.5 million people will be aged 85 years and older. The proportion of adults aged 65 years and older will increase from 13 % to 19 % (Vincent & Velkoff, 2010).

In the EU the number of Europeans aged 80+ will triple by the year 2060 (Eurostat, 2010). The proportion of people aged 80 years and older will rise from 4.4 to 12 %. The proportion of EU citizens aged 65+ will increase over the same period from 17.1 to 30 % (Lanzierie, 2011) (see also Figure 2).

The aging of the EU27 population is a result of the relatively low fertility rate and the increasing number of people getting older. This aging process will occur in all EU member states. It is estimated that by 2060, the proportion of the population aged 65 years or older will be 22 % in Ireland, 25 % in the UK, Belgium and Denmark, 33 % in Bulgaria, Germany, and Slovakia, 35 % in Romania and Poland, and 36 % in Estonia (Lanzierie, 2011). The proportion of people aged 65 years or older in EU member states is estimated to increase to between two and six times what it was in 1960.

According to Eurostat (Lanzierie, 2011), the population of Germany will have dropped dramatically by 2030. Germany will have the oldest population of any country in the EU with 46.2 % of its population aged over 65 years. In contrast, the cities with the youngest median ages in 2030 will be London, Paris, Oslo, and Brussels (Lanzierie, 2011).

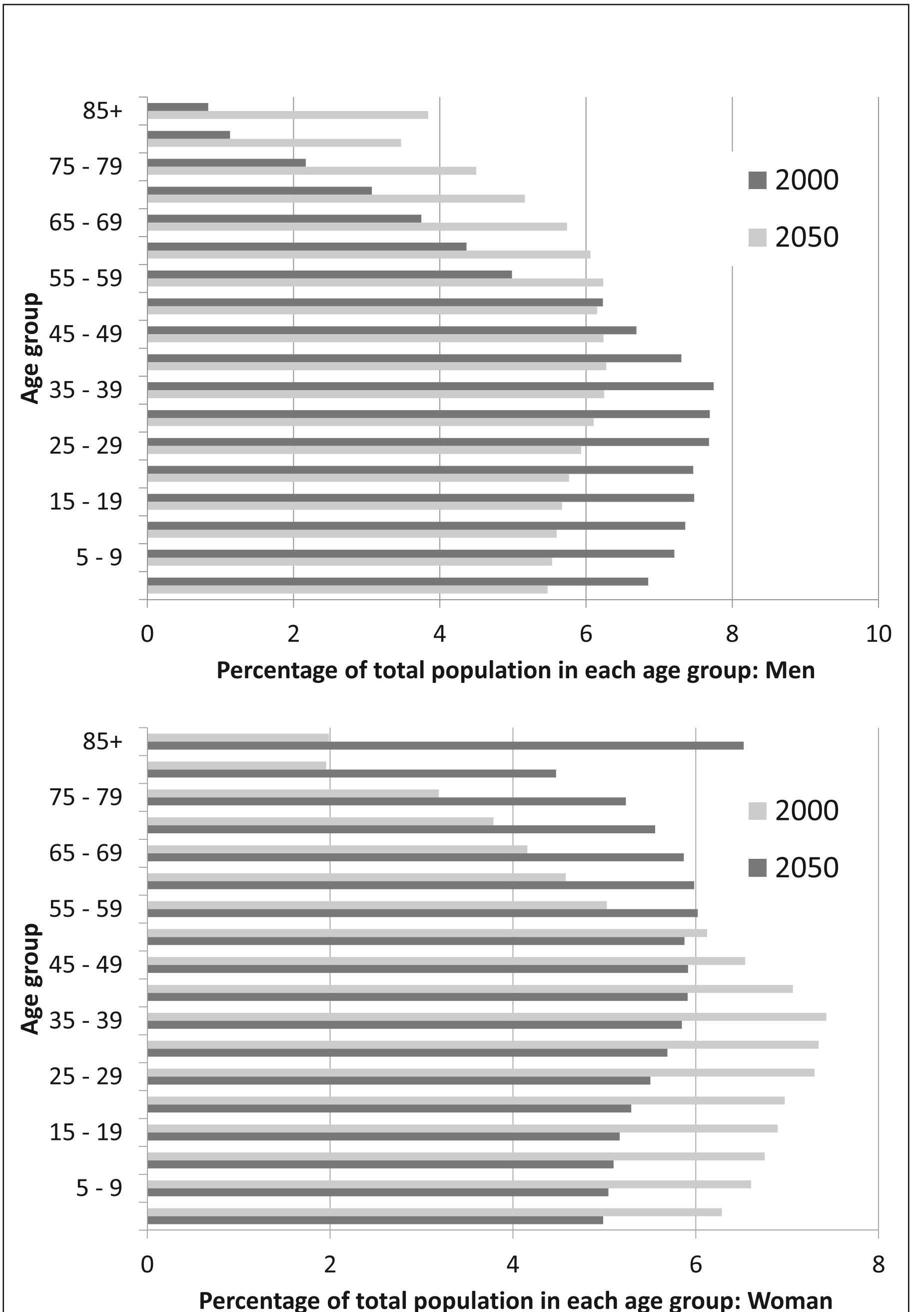

Figure 1: Demographic development in the OECD countries in 2000 and 2050 (own calculation based on OECD, 2007).

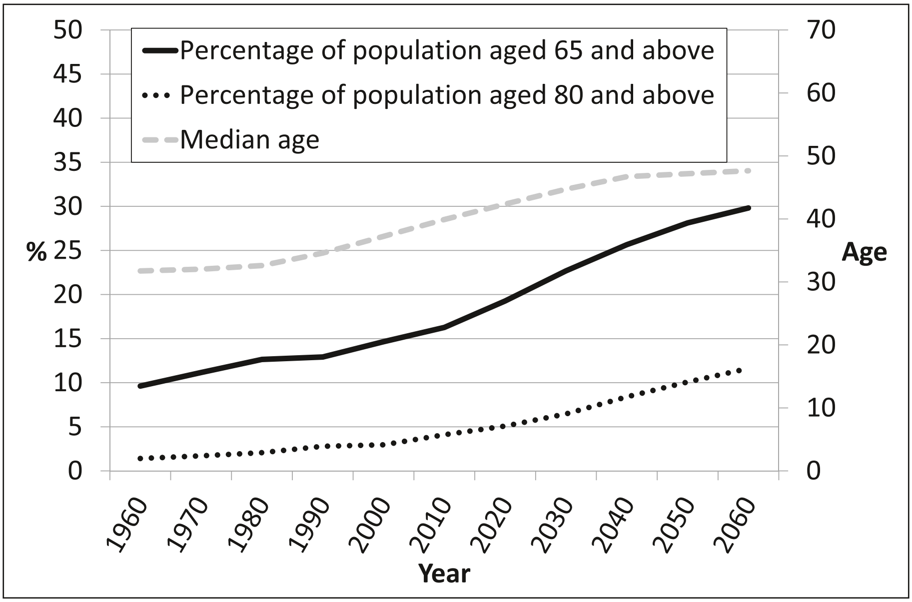

Figure 2: Projected population change in Europe (EU-27) (own calculation based on Lanzierie, 2011).

2.2 Changes in the number of older drivers and their mobility

In general, the proportion of private motorised traffic decreases with age and the proportion of travels made by foot increases (see Figure 3). However, these distributions are likely changing with the new generations of older people.

Senior drivers (65+) are the fastest growing part of the driving population in the industrialized countries (Siren & Kjær, 2011). This trend is even visible for short periods of time (Kalinowska, Kloas, & Kuhfeld, 2007) and is especially valid for elderly woman as shown in Figure 4 (BMVBS, 2010).

This is a common trend throughout most OECD countries. Figure 5 shows an example using data from the USA (Sivak & Schoettle, 2011). This development will continue in the future with projections for Europe suggesting that by 2030, a quarter of all drivers will be aged 65 years and above (OECD, 2001b) (see Figure 6).

The AARP Public Policy Institute (2005) in the USA predicts that one out of every four licensed drivers will be 65 years and above by the year

2029. In the year 2050, half of the 70 million older drivers will be over the age of 75 (McGuckin, 2007). The trend of being increasingly mobile

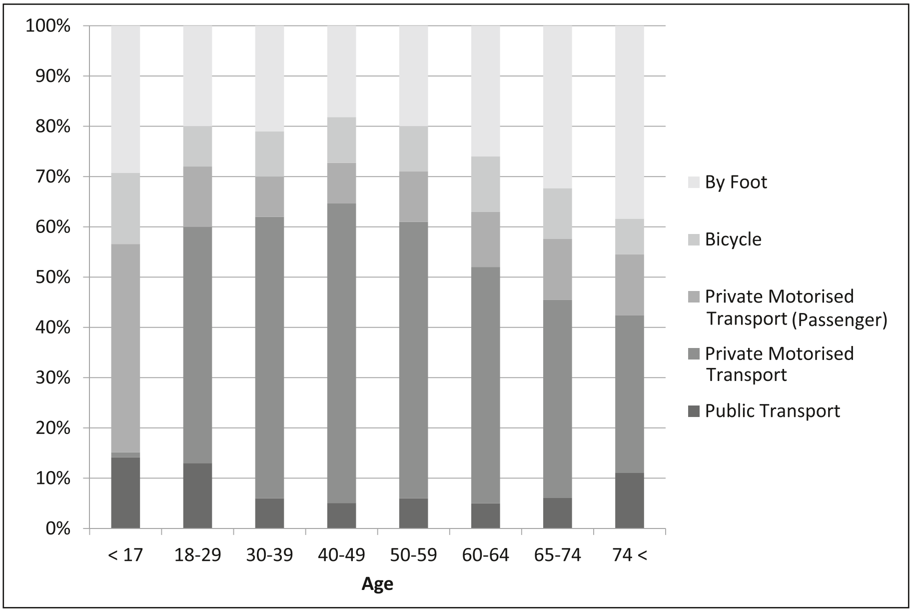

Figure 3: Modal Split by age for Germany, 2008 (proportion of ways by mode of transport by age) (source: BMVBS, 2010).

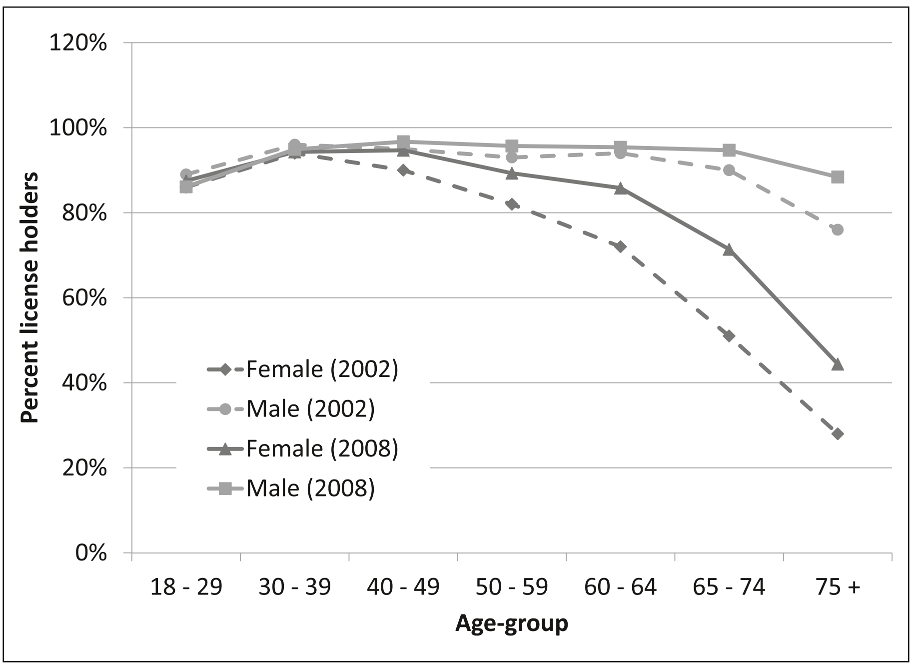

Figure 4: Development of license holders by age group in Germany (2002 and 2004) (based on BMVBS, 2010).

is shown by NHTS data which states that in 1990 only 36 % of 85-95 year old drivers used a car, whereas in 2001 about 45 % still drove by themselves (McGuckin, 2007).

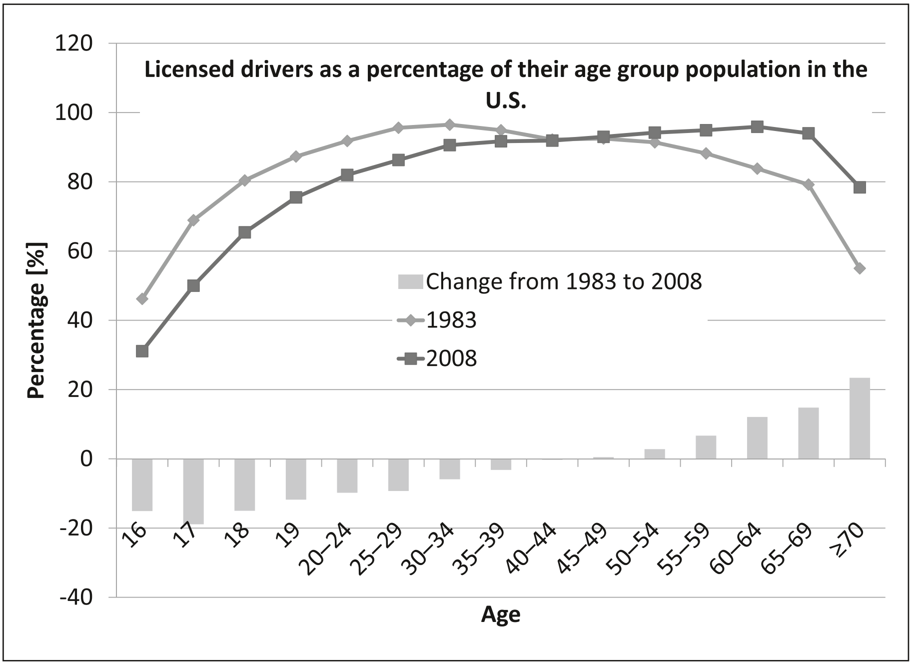

Figure 5: Development of licensed drivers in the USA by age-group between 1983 and 2008 (based on Sivak & Schoettle, 2011).

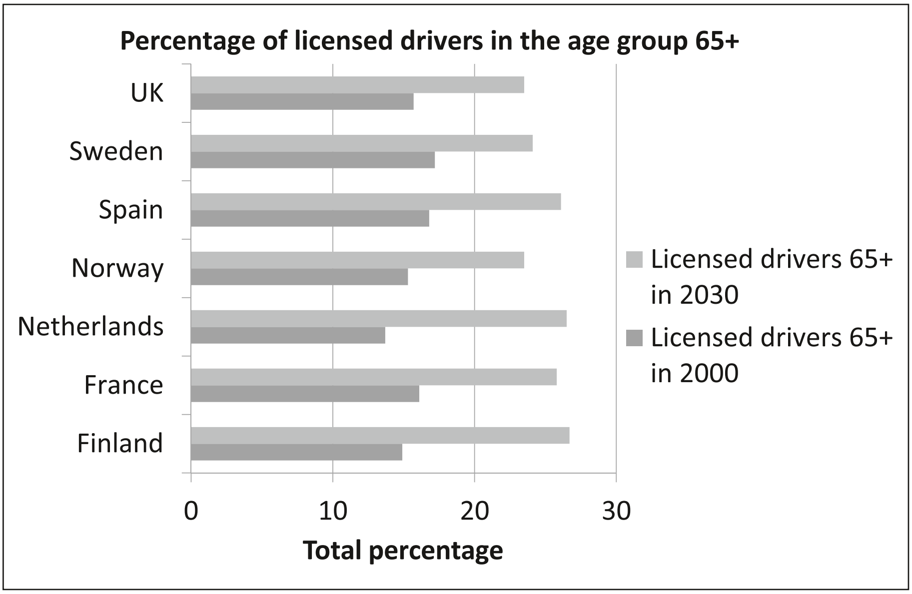

Figure 6: Percentage of licenced drivers in Europe in the age group 65+ in 2000 and 2030 (European Commission Road Safety, 2001, cited in: SaMERU, 2013).

However, despite similarities between the USA and the EU there are some differences. Europe and the USA still differ in the percentage of older female drivers (Rosenbloom, 2001). Whereas in the USA, female license holders have slightly outnumbered male license holders since 2005 (Sivak, 2013), in Europe their percentage is still smaller. However, with the disproportionate increase of female license holders in Europe (see Figure 7) this difference is likely to decline. For the OECD countries, hardly any increases in gender differences in the percentage of license holders are expected by 2030 (OECD, 2001a).

Other differences between Europe and the USA concern the way trips are made. Older people in Europe walk more often than older Americans (Rosenbloom, 2001). This reflects the general difference between the USA and Europe: in Europe, traditionally more trips are made by foot or bicycle (Pucher & Dijkstra, 2003; Rosenbloom, 2001) (see Figure 8).

Another difference between older Germans and older US Americans aged 80 to 84 years can be found in the number of trips by car. Whereas Germans of this age-group make 1.4 trips per day, the American counterparts make 2.7 trips per day (Rosenbloom & Ståhl, 2002). One reason for this difference is better accessibility and acceptance of public transportation in Europe.

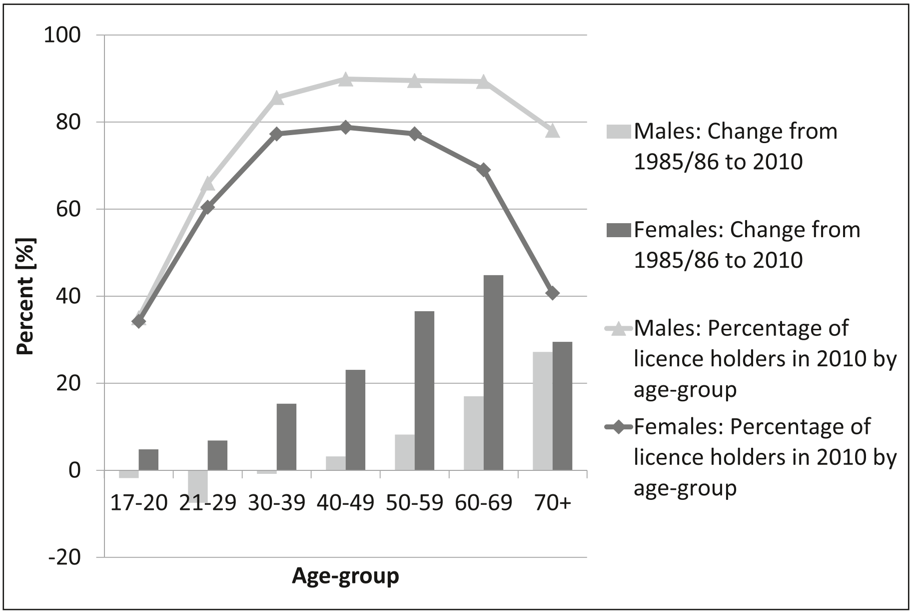

Figure 7: Development of licensed drivers in the UK by gender and by age-group between 1985/86 and 2010 (based on DfT, 2011).

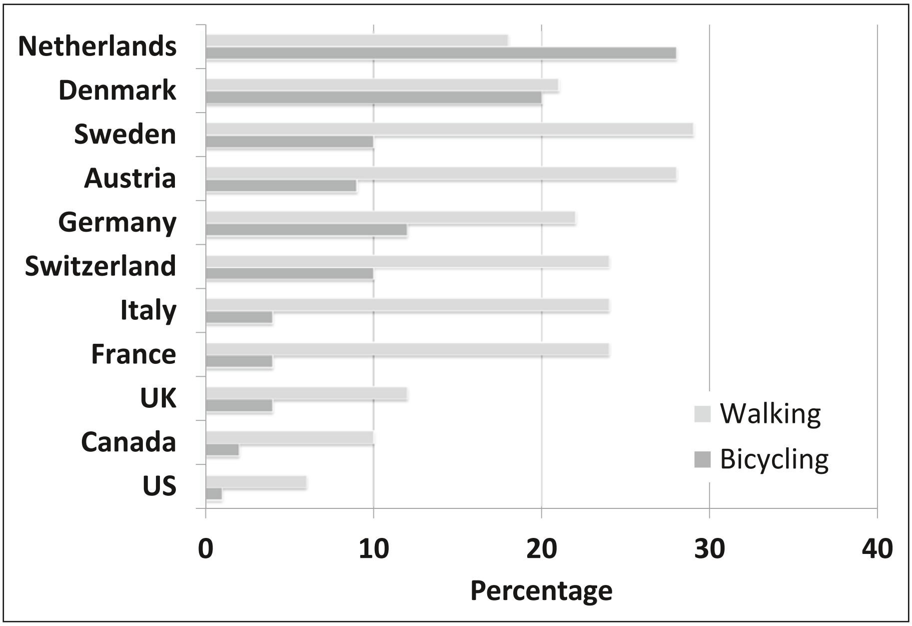

Figure 8: Percentage of trips in urban areas made by walking and bicycling in North America and Europe (Pucher & Dijkstra, 2003).

Despite these differences it can be assumed that the trend in Europe will be similar to the one in the United States where motorization started earlier than in Europe. The factors named before (accessibility and acceptance of public transport) will probably only effect the extent of the changes and not their direction.

An increase in older people's mobility can be seen in Europe that is similar to the United States (ERSO, 2006).

Figure 9 shows the dramatic increase in the average number of daily trips by older people in Germany (BMVBS, 2010). In the United States, daily trips per person made by people aged 65 years and older increased from 2.4 in 1990 to 3.2 in 2009 (Santos, McGuckin, Nakamoto, Gray, & Liss, 2011). This increase was greater than for any other age group (Santos et al., 2011). Nevertheless, older Americans and older Europeans still drive fewer miles and make fewer trips than younger ones (J. M. Lyman, McGwin Jr., & Sims, 2001; Shinar, 2007).

As the current aging generation is the first generation to have grown up driving a car, it can be assumed a large amount of these trips will be made by car. Older drivers do not only drive until an older age they also drive more kilometers than previous cohorts (Berry, 2011; Eby &

Molnar, 2009). The average annual number of vehicle miles travelled for older adults has also dramatically increased from 7,084 in 1990 to 8,250 by the year 2009 (Santos et al., 2011).

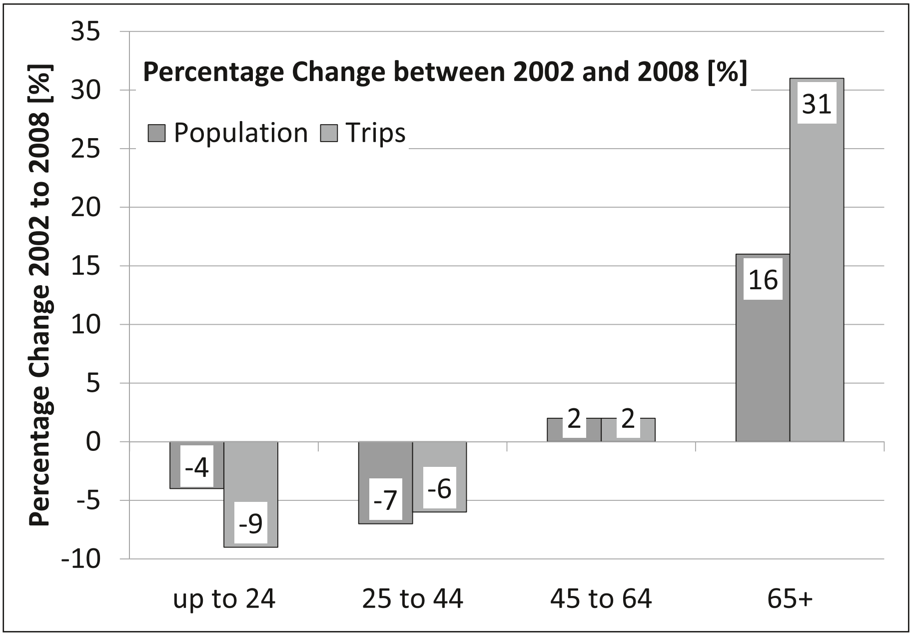

Figure 9: Percentage change in population and trips per age-group in Germany (BMVBS, 2010).

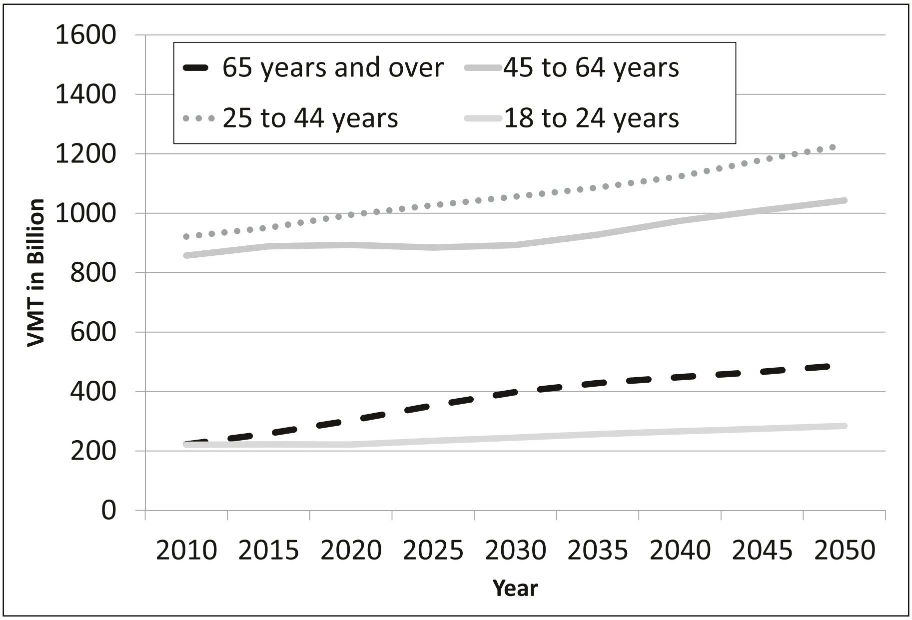

Figure 10: Projection of Vehicle Miles of Travel for the United States by age group (source: own calculation based on data from U.S. Department of Transportation & Federal Highway Administration (FHWA), 2009; United States Census Bureau, 2008).

A further dramatic increase is projected until 2050 (see Figure 10) leading to an increased number of expected fatalities of older drivers (McGuckin, 2007).

2.3 Changes in the number of older drivers in partner cities: An example from Modena

As described in the previous chapter, the percentage of older drivers is currently increasing and is expected to increase further until 2050. In this chapter the situation in selected partner cities and boroughs is presented.

Figure 11 shows the percentage change of drivers per age group in Modena between 2009 and 2011. Whereas the number of drivers aged 85+ increased by nearly 40 %, the figures for younger age groups actually declined. This general trend is also depicted in the linear trend line.

In Italy, licenses have to be renewed according to set intervals, depending on the age of the driver (ranging from every ten years for drivers aged under 50 years up to every two years for drivers aged 80+) (see SaMERU, 2013). Therefore, the increase in the percentage of active

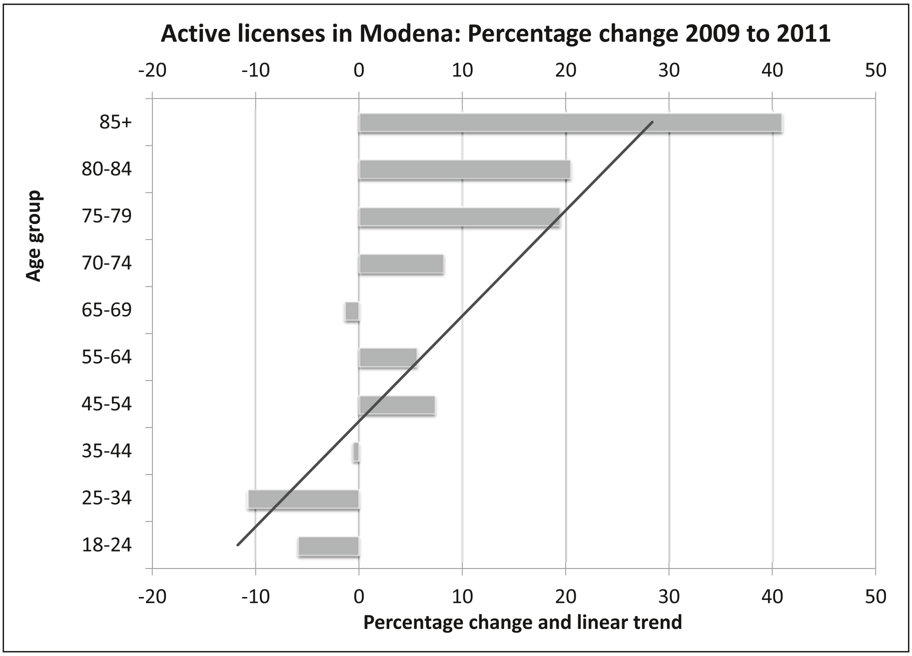

Figure 11: Active licenses by age group in the Province of Modena from 2009 to 2011 (source: SaMERU, 2013).

driving licenses for the elderly means that these people actively renewed their licenses and were regarded as fit to drive by a medical doctor. In this respect these changes might reflect a more realistic picture of active drivers than for countries that do not have a renewal policy.

3 Age-related changes in abilities

Although some parts of the driving task are done automatically (see Groeger & Clegg, 1997, for a discussion) others require conscious decision-making. This is the case in unknown or unexpected situations and results in a change of processing level (Ranney, 1994; Rasmussen, 1986). Generally speaking, demands placed on people when in traffic particularly when driving a car are manifold and require all aspects of information intake, cognitive processing, decision making and action execution. Although car-driving is ostensibly a self-paced activity, many decisions must be made under time pressure. This is especially the case in complex inner-city situations which are characterised by a vast amount of relevant and irrelevant information.

However, many aspects of sensory, cognitive and motor ability show a decline with age and thus, probably result in a degradation of car-driving quality and safety. Before focusing on car driving it should be noted that this decline in capability also results in limited accessibility to all other means of transportation, albeit to a varying degree depending on the means of transportation (Schlag, 2008c). Figure 12 gives an overview of potential declining abilities with age (Schlag,1993,1999).

The start of information processing is sensory perception which gradually degrades with age. However, the rate and degree of decline varies greatly between individuals and also between parameters. Sight is the most important sense when driving (Sivak, 1996) and as such decreased visual function is the most relevant for the driving task.

Visual acuity declines with age. By reviewing several studies and also collecting their own data, Haegerstrom-Portnoy found that “high contrast acuity is very well maintained on average until age 65 to 70 years. At later ages, our results, like others, show that acuity declines” (Haegerstrom-Portnoy, Schneck, & Brabyn, 1999, p. 150). The fact that the amount of decline varies considerably between the studies analyzed is attributed to several factors. Among these are cohort effects, differences in the acuity charts used, and sampling effects.

It is important to note here that this decline in visual ability is not restricted to a mere decrease in visual acuity. In addition to visual acuity, many other aspects of visual function are affected by this decline with age. Glare recovery and contrast sensitivity are especially important for driving at dusk or dawn and both of these decline with age (Haegerstrom-Portnoy et al., 1999; US DoT, 2002). Furthermore, the useful field of view (UFOV) declines (US DoT, 2002).

Besides visual function itself, the quality of visual behaviour declines. Reed, Kinnear, and Weaver (2012) found that scanning times to the left

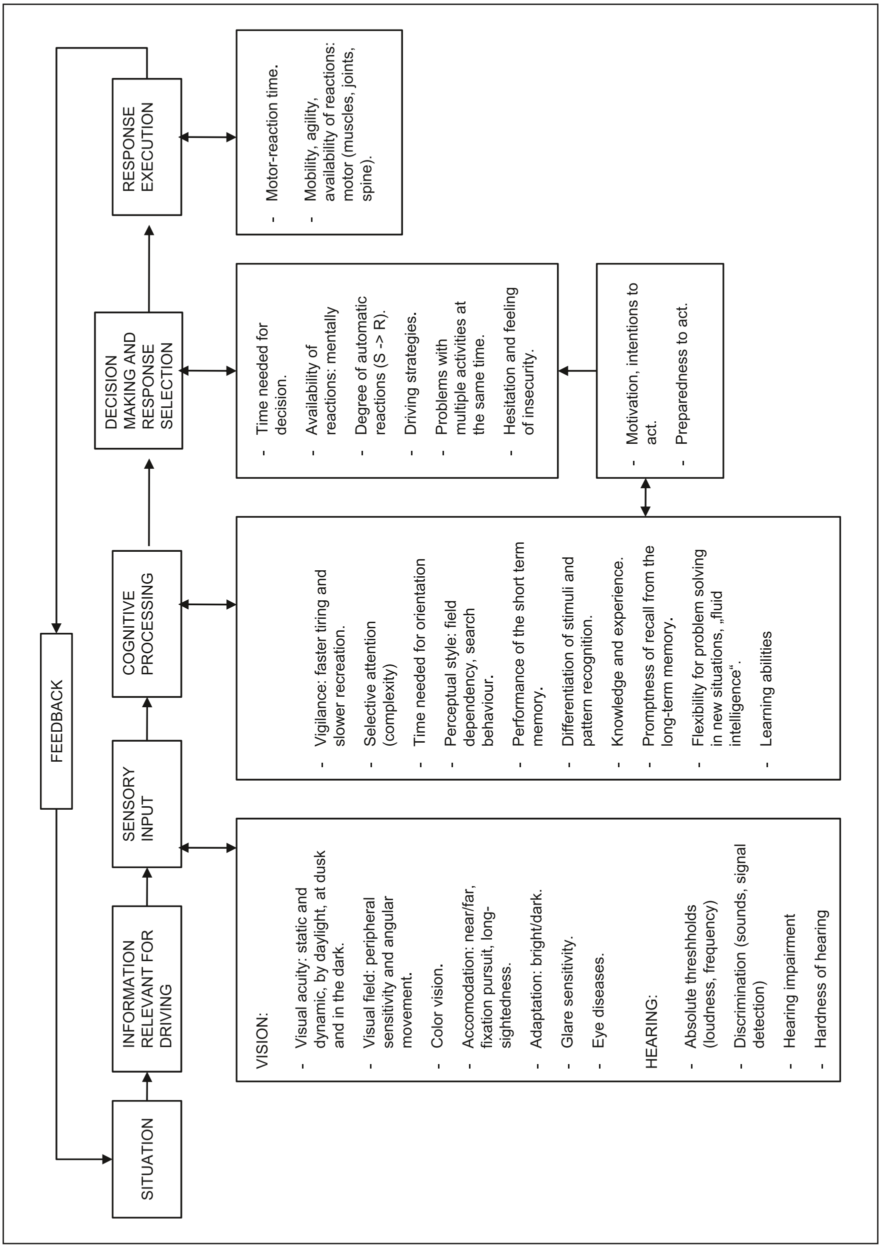

Figure 12: Age-related changes in abilities (Schlag, 1999).

and right at intersections were shorter for older people than for younger comparison groups. However, no negative effects resulting from this behaviour were found in this study.

A closer analysis of gaze behaviour by Dukic and Broberg (2012) found similar results but could also specify that younger drivers spent more time fixating on potential threats (usually moving objects) while older drivers focused on static elements such as road markings, signs or traffic lights.

Bao and Boyle (2009) also found that older drivers (65+) showed reduced scanning behaviour to the left and right at intersections when compared to young (18-25 years) and middle aged drivers. Apart from intersections, the scanning behaviour of both the youngest and the oldest drivers was worse than the behaviour of the middle aged drivers.

Research also showed that older drivers showed differences in scanning behaviour to mirrors. Bao and Boyle (2009) found that older drivers checked the rearview mirror less than younger drivers. This was also found by Weller, Sturmeit, Schlag, and Gehlert (2013) who additionally found that older drivers, when changing lanes and overtaking, looked back significantly less than a younger comparison group (see Figure 13).

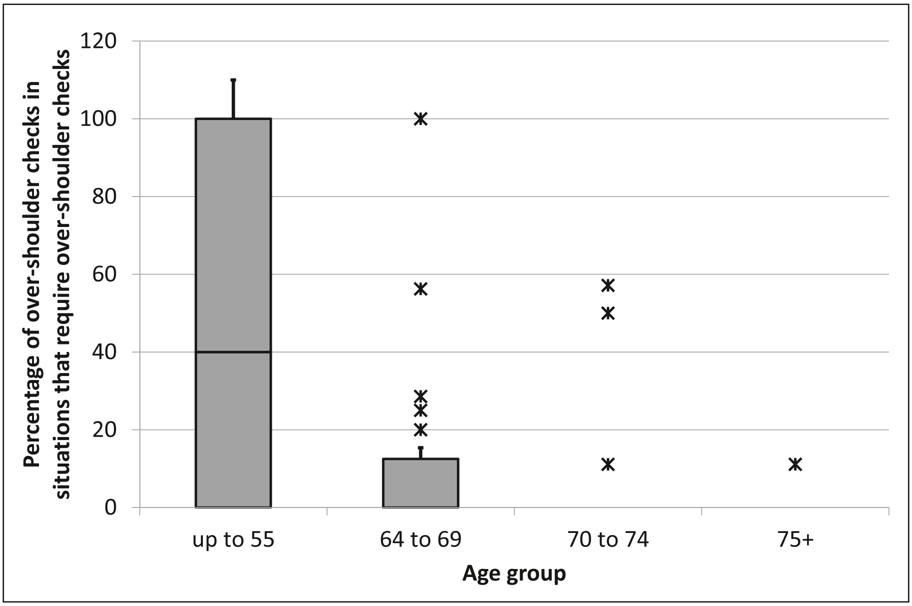

Figure 13: Percentage of situations with over shoulder checks which require over-shoulder checks (Weller et al., 2013).

Figure 12 shows the chain of information processing and related age changes in abilities. As can be seen, the next step after sensory information input is information processing. This processing of information is usually denoted as cognitive ability. Cognitive ability also comprises several facets which are all affected by aging.

Perhaps the most important of these changes in terms of traffic participation is the decline in all aspects of attention including declining sustained attention (vigilance), declining selective attention and declining divided attention (Schlag, 2008c; Weller & Geertsema, 2008). These aspects of attention are particularly relevant in complex situations or when solving complex problems (Salthouse, Rogan, & Prill, 1984).

Vigilance is needed to maintain a high level of attention in sustained situations. However, because driving is a self-paced task (at least at the navigational level) this latter aspect might be of lesser concern for older drivers because they can interrupt driving and continue after a short or long break. However, it is not so easy to compensate for the decline in divided attention. Divided attention is required in most driving situations and a failure to divide attention will result in the wrong situations being attended to.

It is important in this context that a decline in attentional capability is not necessarily observable as a decrease in performance. Bunce and Sisa (2002) found no such decrement but they did find an increase in subjective workload. This pattern is very indicative of the A3 region in de Waard`s workload model (de Waard, 1996) in which effort must be invested to compensate for increasing demand (see Figure 14). The problem with it being in this region is that declining abilities might not be picked up by performance-based tests and only come into effect when drivers are subjected to these kinds of conditions for a longer period of time.

The combination of declining sensory functioning and declining cognitive abilities result in longer overall reaction times, particularly in complex situations (Hancock, Lesch, & Simmons, 2003; Horberry, Anderson, Regan, Triggs, & Brown, 2006) (see decision making and response selection in Figure 12).

This resource-based prolongation of reaction time is also affected by an increase in decision time (Salthouse, 1996). This means that older drivers need more time to react both to standard situations such as traffic sign information, and to unforeseen situations.

Furthermore, reaction time is affected by greater inconsistencies in decision time (Bunce, MacDonald, & Hultsch, 2004). Bunce et al. (2004)

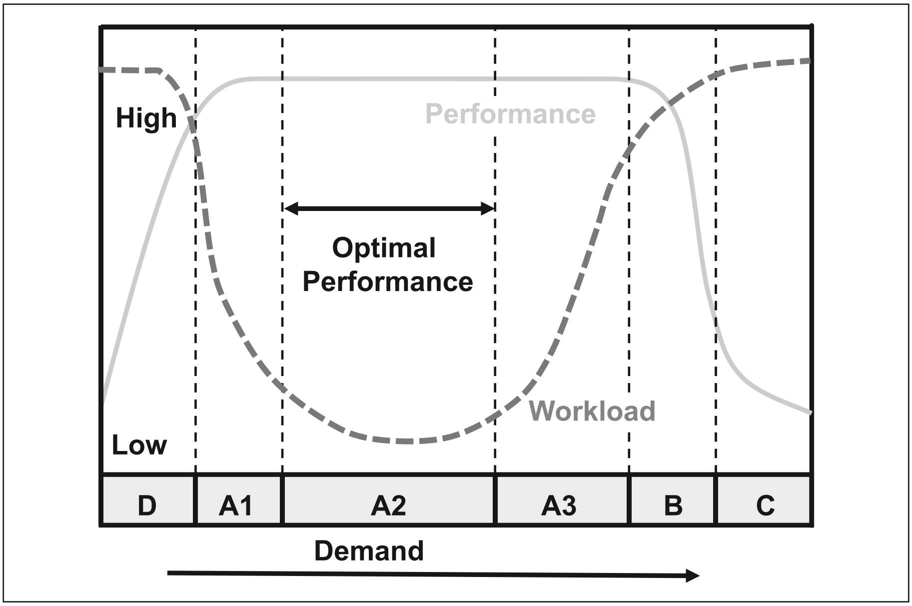

Figure 14: Relationship between demand, workload, and performance (De Waard, 1996).

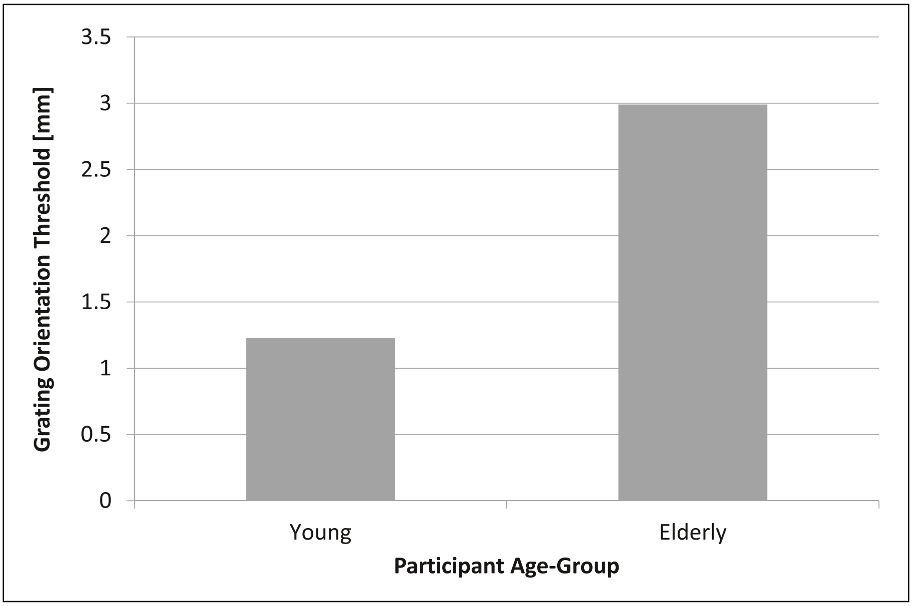

Figure 15: Age-related differences in the grating orientation threshold (Norman et al., 2011).

defined these inconsistencies as the intra-individual standard deviation of decision time (ISD) which was corrected for each age group. Such correction was performed to compensate for an automatic increase in ISD which would otherwise result solely as a consequence of the age-related increase in mean reaction times.

Response execution, the last step in the chain of reacting to sensory input (see Figure 12), is also affected by an age-related decline in sensorimotor and physiological changes (Rinkenauer, 2008). Reduced muscle strength and motor flexibility results from a general decrease in muscle mass and changes in muscle density and consistency (Rinkenauer, 2008).

In addition to restricted motor function and the decline in visual and auditory functions as shown in Figure 12, the sense of touch is also affected. Figure 15 shows the difference in the grating orientation threshold[1] which increases with age. Kleinman and Brodzinsky (1978) also found a degradation of haptic perception with age (see Figure 16).

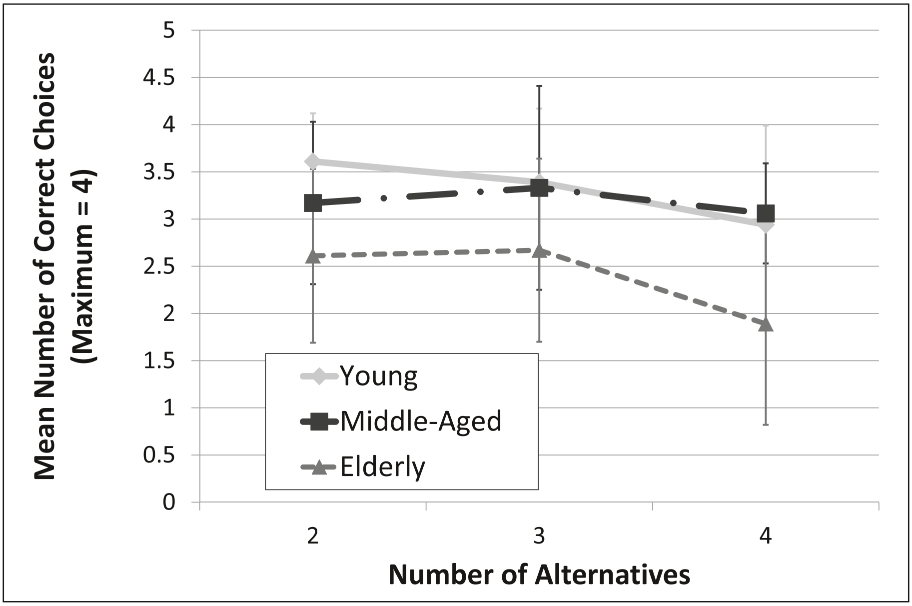

Figure 16: Age-related differences in the number of correct choices in a haptic comparison task (Kleinman & Brodzinsky, 1978).

1 The grating orientation threshold is a measure for human tactile spatial resolution. It is assessed by pressing dome shaped forms on the skin of a participant and asking the participant for the orientation of the pattern on the form (GOT: Grating Orientation Task). The pattern itself consists of equidistant parallel bars and grooves. The distance ranges between less than one and several millimeters. A smaller result-value represents a smaller threshold and thus indicates higher sensitivity. A picture of such JVP domes is shown in van Boven et al. (2000).

However, Norman et al. (2011) found that “tactile acuity is strongly affected by aging, but the ability to haptically judge surface shape is preserved” (Norman et al., 2011, p. 915). This indicates that a differentiation must be made between tactile and haptic sensitivity. The difference between tactile and haptic perception is simply that tactile denotes the passive stimulation of the skin whereas haptic means the active exploration of an object (surface) including “both the cutaneous sense and kinesthesis” (Grunwald, 2008, p. 649) by using exploratory movements as described by Lederman and Klatzky (1987, cited in Klatzky & Lederman, 2012).

What effect do these age-related changes have on traffic safety? Although traffic safety of older drivers is dealt with in detail in subsequent chapters some general facts are given here.

In general a low to moderate relationship between measures of age, sensory, cognitive and motor ability and driving performance and accident involvement have been found (see also Chapter 7). Anstey, Wood, Lord, and Walker (2005) reviewed sixteen empirical studies and found such low to moderate associations. However, relationships based on such low to moderate correlations would never be suitable to distinguish reliably between drivers being at risk of having an accident and drivers not at risk.

It must also be pointed out that the literature is inconsistent regarding the relationship between capability and driving safety. For example, Ellinghaus, Schlag, and Steinbrecher (1990) and Schlag (1994) found that older participants were much worse than younger ones in different laboratory tasks but this was not matched by a similar pattern when driving on the road. The reason might be that in the laboratory the elderly use a strategy that trades faster responses for higher precision.

Another factor identified by Anstey et al. (2005) is the ability of self-monitoring and beliefs about driving capacity (see Figure 17). Self-monitoring is also associated with self-image (see Chapter 6) and both are probably indicative of the amount of compensatory behaviour in driving (see Chapter 9.1).

An interesting aspect of the model by Anstey et al. (2005) is that chronological age is entirely left out. This is in accordance with the literature which notes that older drivers are a very heterogeneous group

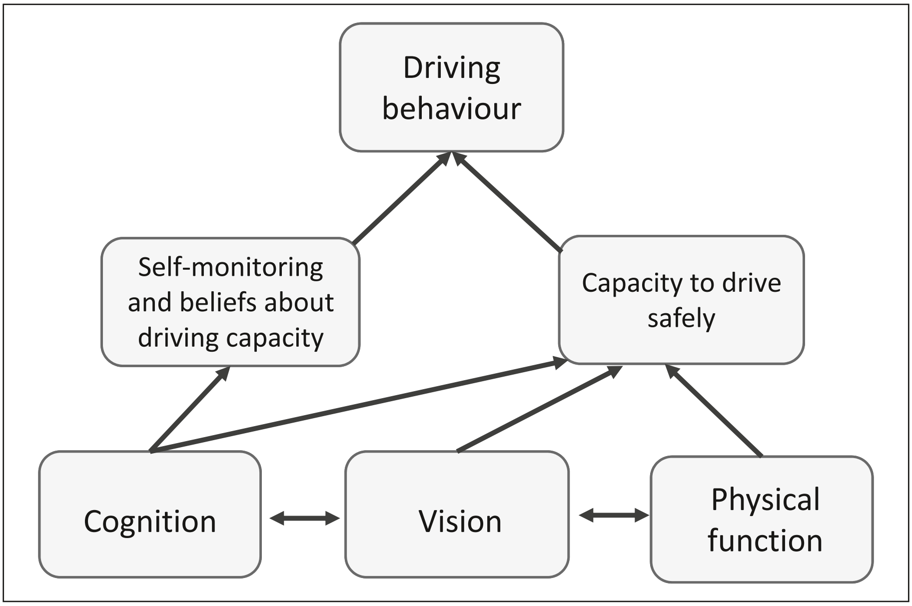

Figure 17: Schematic model of factors enabling safe driving behaviour as proposed by Anstey et al. (2005).

characterised by high inter-individual and intra-individual differences in capability (Schlag, 2008a). Although there is an age-related decline in abilities the development of this decline differs greatly between individuals. This is exemplified in a study by Buld, Hoffmann, and Krüger (2006) who examined entry behaviour onto motorways. They found that both the driver with the lowest amount of driving errors and the one with the highest amount belonged to the oldest age group.

Further details of age-related declines and their effect on traffic safety, especially for pedestrians are provided in SaMERU's WP1 reports. In a publication by Staplin et al. (1997) the relationship between the age-related decline and accidents is summarized. If a relationship between decline and accident involvement was found at all, this was usually small. In general, understanding the age-related impairments described above is a prerequisite for designing a traffic environment which is more compatible with the impairments of older driver (see Chapter 9).

4 Health issues and medication and their influence on driving ability

In addition to age-related changes, health issues such as cataracts, dementia, diabetes mellitus, strokes, cancer, heart attacks or osteoarthritis occur more frequently with increased age in comparison with younger people. However, diagnosing an illness is not reason enough to take away a person's drivers licence. More decisive are any functional limitations that result from the condition and whether they have an influence on driving ability or being fit to drive. Therefore, it is necessary to take a closer look at the correlation between age-related ailments and traffic safety. This correlation needs to be discussed with consideration of any medication that is being taken and its influence on safe road use.

A number of studies have shown that there is an increased risk of accidents due to health conditions such as dementia, eye disease, heart and circulation illnesses, neurological and psychiatric illnesses and metabolic disorders (Ewert, 2008). Studies (Charlton et al., 2004) have also shown that conditions such as sleep disorders, impaired vision, cataracts, glaucoma, alcohol problems, nervous system disorders, and psychiatric disorders are associated with the highest risk of an accident. Anxiety disorders, untreated diabetes, depression (both treated and untreated) are also related to a significantly increased risk of accidents (Sagberg, 2006).

In order to adequately assess driving ability, it is necessary to define the physical functions and structures which are the prerequisites for safe driving (Ewert, 2008). However, it is also necessary to understand to what degree these physical functions and structures are reduced due to a specific disease or medication and what possibilities there are to compensate for this (Ewert, 2008).

Furthermore, it must be kept in mind when assessing driving ability that older people regularly suffer concurrently from various conditions and often it is the case that different medication is taken simultaneously. The interaction between these medications can have an influence on driving ability.

It is vital to provide elderly people with comprehensive information about the influence of health conditions, medication and mixing medication because there is an increased probability that they will have some sort of condition in their older years and require medication (Sagberg, 2006). Their consulting physician plays a key role in this. Doctors are particularly important when assessing driving ability (Eby & Molnar, 2009). They could be actively involved in recognising early-on any reductions in driving ability in older patients as part of general treatment, consultation and prescribing medication. They could also point out possible ways of compensating for these deficits, so that driving ability can be maintained (D'Ambrosio, Coughlin, Mohyde, Gilbert, & Reimer, 2009). However, studies have shown that doctors are unwilling to make decisions about the driving ability of older drivers (Jang et al., 2007). There is also evidence from an Australian study (Sargent-Cox, Windsor, Walker, & Anstey, 2011) that doctors only very rarely allude to possible problems for driving a vehicle that are a result of the current physical health of a patient.

5 Mobility pattern of older drivers

The car is an important means of transport for elderly people despite age-related changes that effect driving. Elderly people use a vehicle for two-thirds of their journeys even though their overall driving performance drops with age (see Chapter 7.1).

Before describing accidents involving elderly drivers, accidents involving elderly people using other means of transportation should be mentioned. Figure 18 shows that besides drivers and car passengers, the share of accidents involving elderly cyclists increased dramatically between 1980 and 2010. Although cyclists are not the topic of this report, future studies should focus on this area of elderly mobility.

However, when it comes to car-driving, elder drivers adapt their behaviour. In addition to reduced overall performance, older drivers also avoid situations that they see as risky, for example, they drive less during bad weather conditions, in peak hour and at night (Ball et al., 1998).

Also typical for older drivers is a decrease in traffic violations such as speeding and driving under the influence of alcohol (Langford & Koppel, 2006; S. Lyman, Ferguson, Braver, & Williams, 2002).

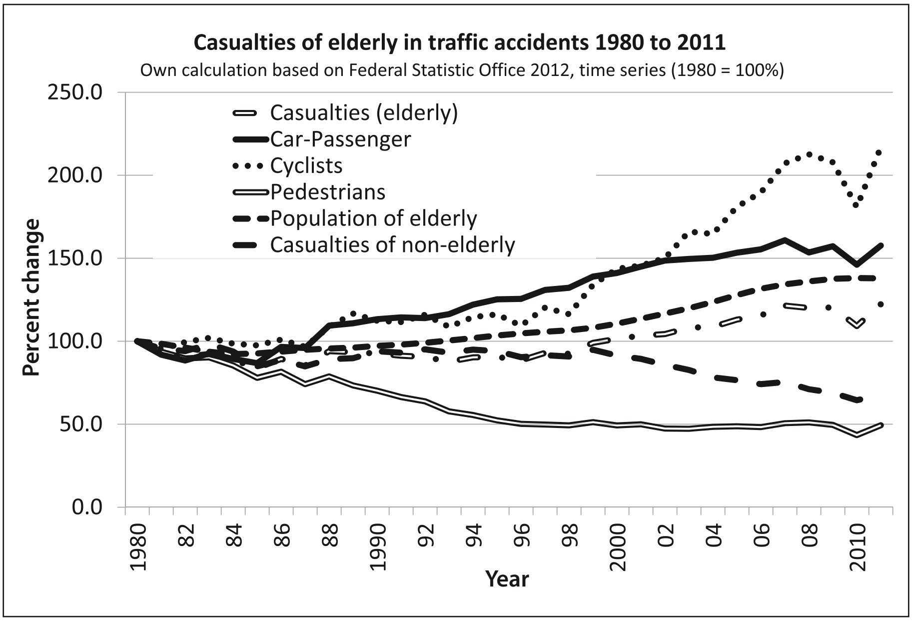

Figure 18: Casualties of elderly in traffic accidents in Germany (Statistisches Bundesamt, 2012b, own calculation).

Schade (2008) summarised the mobility behaviour of older drivers as follows:

- The proportion of people who leave their house at least once per day decreases with age.
- Older people do less trips per day than other age groups.
- Older holders of a drivers licence do less trips per day than in other age groups.
- With increasing age, the length of trips made by elderly drivers decreases.

What are the reasons for this development given the decreasing sensory capabilities with age? In fact, it is probably the result of compensation behaviour, namely to avoid driving at night (Schlag, 2008c). However, elderly drivers are less likely to travel in poor weather, drive on busy roadways or during rush hour (Ball et al., 1998). This is supported by German data showing a decrease in drives after 8 pm and the majority of drives being between 9 am and to 2 pm (Infas/DLR, 2008), which is shown in Figure 19.

Porter and Whitton (2002) established that older people drive slower and often do not stop at all at stop signs. Buld et al. (2006) used a driving simulator to study the driving performance of different age groups when entering the autobahn. This also showed that older people drive too

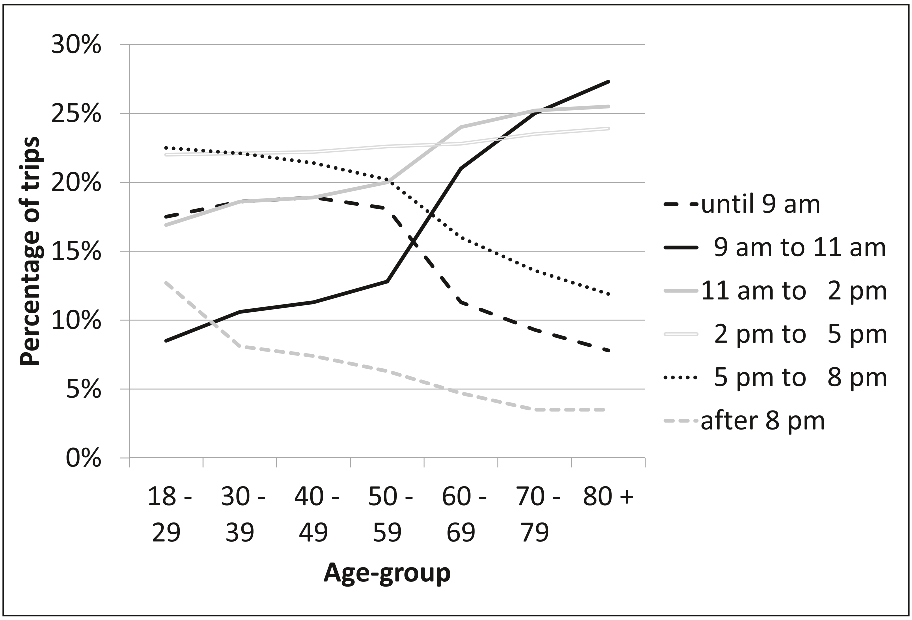

Figure 19: Driving time by age group in Germany (Infas/DLR, 2008, own calculation).

slowly and regularly break more heavily than test drivers in other age groups. On the other hand this leads to older drivers being more likely to obey speed limits (S. Lyman et al., 2002).

In summary, the findings for mobility behaviour are in line with the Selective Optimization with Compensation (SOC) Model (Baltes & Baltes, 1990). Studies show that older people are psychologically quite capable of dealing with age-related performance losses and adjust their driving frequency and driving behaviour to compensate for perceived age-related changes (see also Chapter 3).

5.1 Mobility pattern of elderly road users in partner cities

When dealing with mobility patterns of elderly drivers, the first thing that comes to mind is the time of day they travel. One way to learn when elderly people travel is analysing the accident data. In order to do this the SaMERU partners compared the distribution of all accidents and of accidents involving at least one elderly person across the 24 hours of a day.

It is striking how similar both the data from Modena (see Figure 20) and the data from Southend (see Figure 21) are. They both show a peak in accidents involving an elderly person between 9:00 am and noon. This period is outside the morning rush-hour indicating some adjustment in the daily routine of elderly people. Not surprising is the fact that hardly any accidents involving elderly people happen between midnight and 6:00 pm. These results for Modena and Southend are supported by the literature and other statistics.

However, when aggregated for night-time, slight differences between both cities become visible. As can be seen in Figure 22, the percentage of night time accidents is, in general, higher for Southend where the percentage of accidents involving elderly people is also higher.

The picture becomes even more pronounced when fatalities, not accidents, are analysed. As can be seen in Figure 23, there are no fatalities of elderly (65+) at all during the night whereas 29 % of fatalities of under 65s occur during the night.

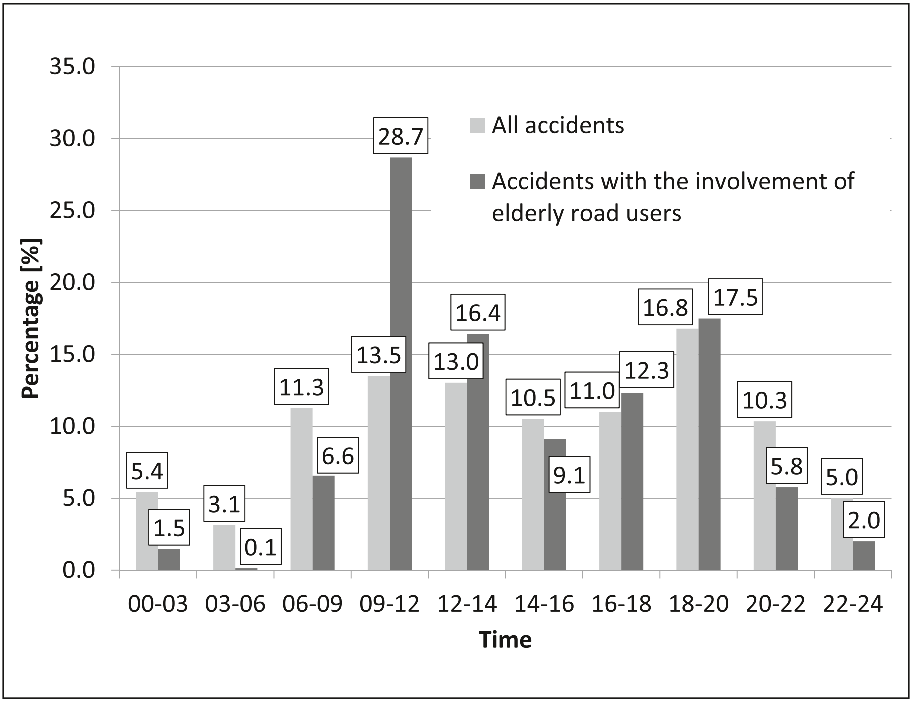

Figure 20: Distribution of all accidents and accidents with elderly road users (65+) by time of the day in Modena between 2006-2010 (source: SaMERU, 2013).

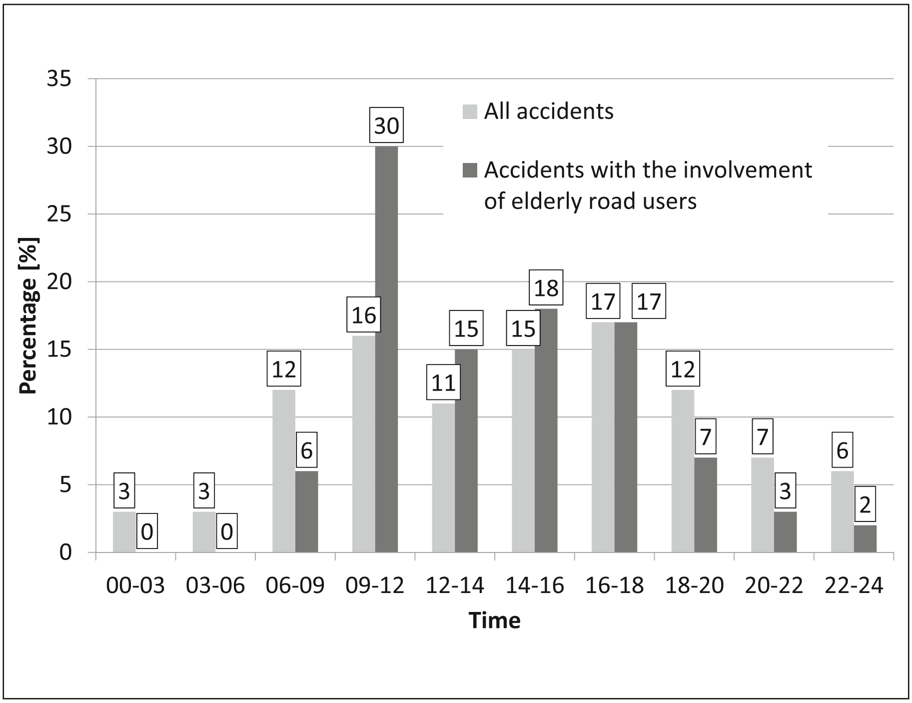

Figure 21: Distribution of all accidents and accidents with elderly road users (65+) by time of the day in Southend between 2006-2010 (source: SaMERU, 2013).

In Lancashire almost 87 % of older casualties occurred in the 12-hour period after 06:00 am with less than 1 % in the 6-hour period before 06:00 am (Figure 24). This pattern contrasts with the wider distribution over the day in the younger age groups.

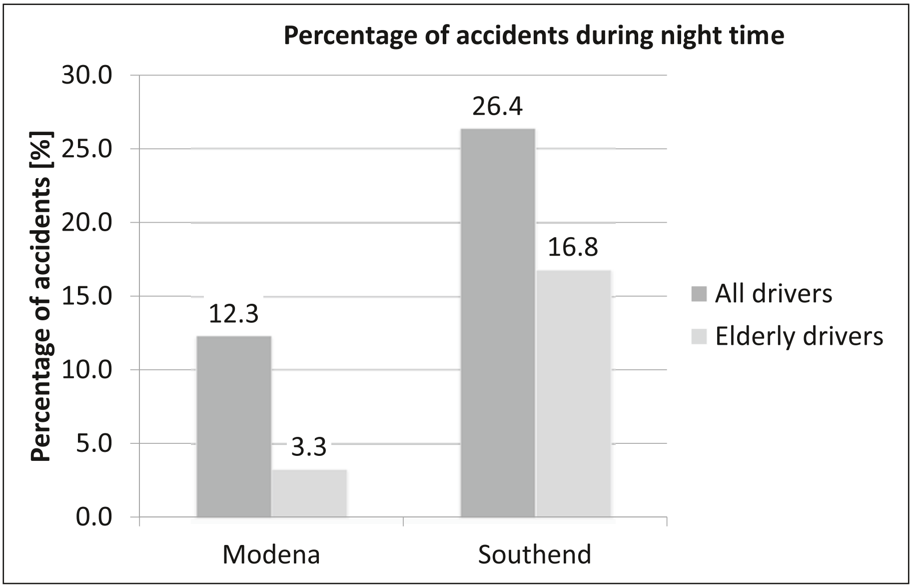

Figure 22: Percentage of night accidents of all drivers and elder drivers (65+) in Modena and Southend (data covering years 2006 to 2010) (source: SaMERU, 2013).

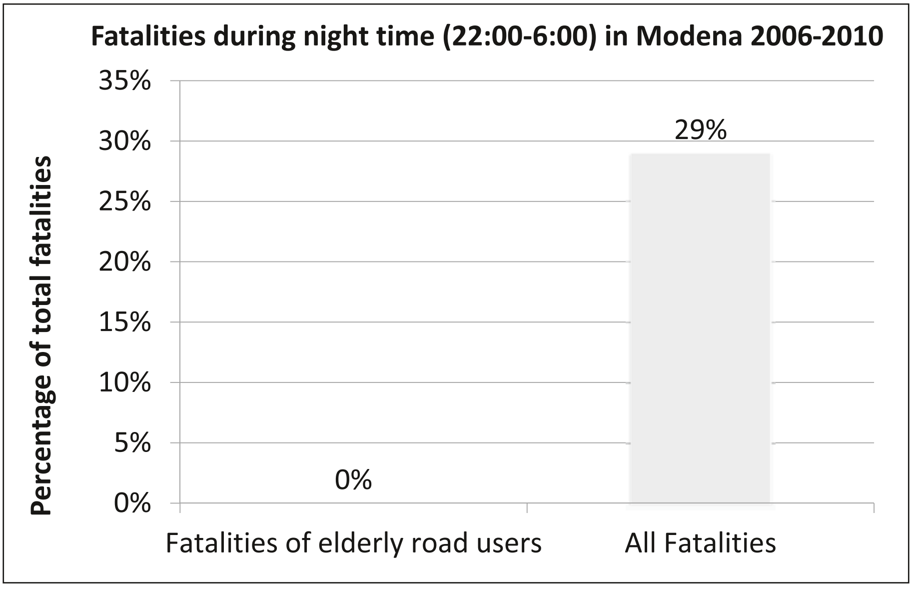

Figure 23: Fatalities during night time in Southend 2006-2010 (source: SaMERU, 2013).

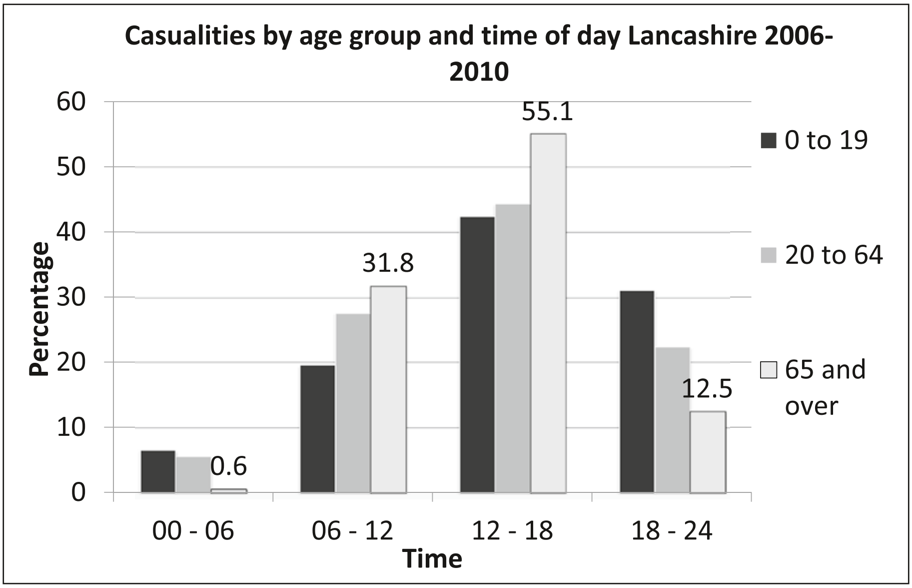

Figure 24: Casualities by age group and time of the day in Lancashire 2006-2010 (source: SaMERU, 2013).

6 Values and self-image of older drivers

Generally speaking, driving a car is positively associated with quality of life, functional independence, and physical and mental health (Li, Braver, & Chen, 2003). Driving appears to delay physical and mental degradation in the elderly because it assists in maintaining social contact and helping with activities in their daily life (Berry, 2011). There is also evidence that a loss of mobility is associated with depression (Fonda, Wallace, & Herzog, 2001). Furthermore, the risk of requiring ongoing care is five times greater for people who have stopped driving a car for more than 6 months (Freeman, Gange, Muñoz, & West, 2006).

Thus, mobility can be seen as a decisive factor in maintaining the quality of life in the aged. Access to a car or other transport enables an independent and active life and as such has an impact on a positive self-image, which in turn significantly contributes to well-being, psychological health and successful ageing (Leipold & Greve, 2008).

Provided that age-related deficits do not result in a person giving up driving a car altogether (see Chapter 10), they appear to have almost

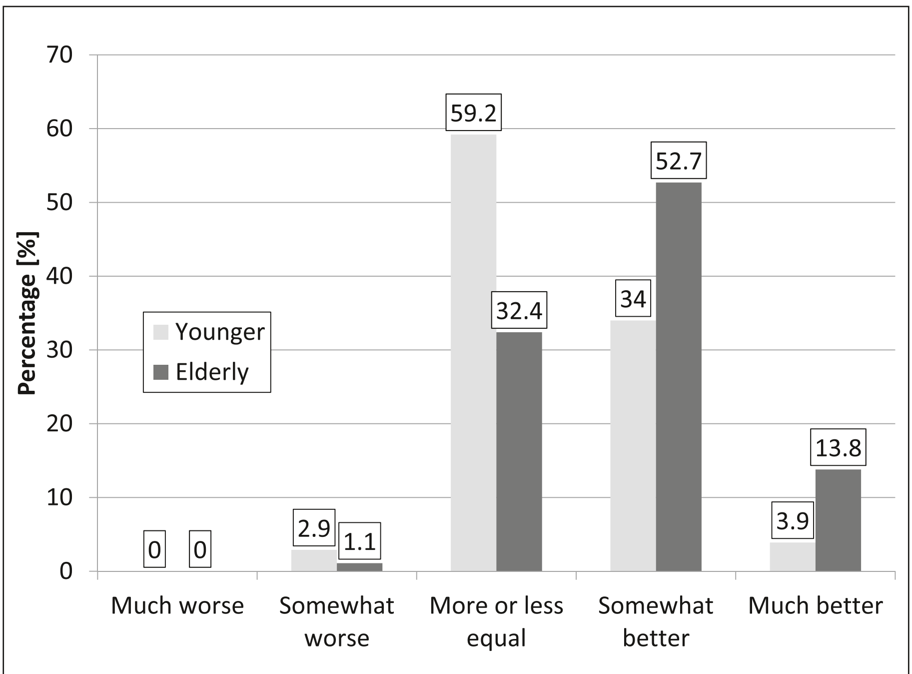

Figure 25: Distribution of answers to the question: Compared to your own age group: how good do you think you would perform in a driving test? (Richter et al., 2010).

no influence on self-image (Kaiser, 2008). This also applies to the self-assessment of driving ability by older drivers. Although the "better-than-average" phenomenon (Williams, 1998) and "degree of expertise" (Waylen, Horswill, Alexander, & McKenna, 2004) are wide-spread across all drivers regardless of age, they appear to be particularly prevalent in older drivers. Richter, Schlag and Weller (2010) found that when comparing older people with younger people, older drivers rate themselves as being significantly better at driving than others in their own age group (see Figure 25). A surprising result from the Richter et al. (2010) study showed that when comparing themselves with younger drivers, older drivers rated themselves as being just as good and in fact a third of them rated themselves as being better drivers (Richter et al., 2010). This global rating of driving can be better understood when other aspects of self-assessment are considered.

Richter et al. (2010) found that older drivers rated their driving style as safer, more cautious, more patient, more compliant, more placid, more exemplary, more attentive and more anticipatory but also more overwhelming when compared to younger drivers. Examining a sample of

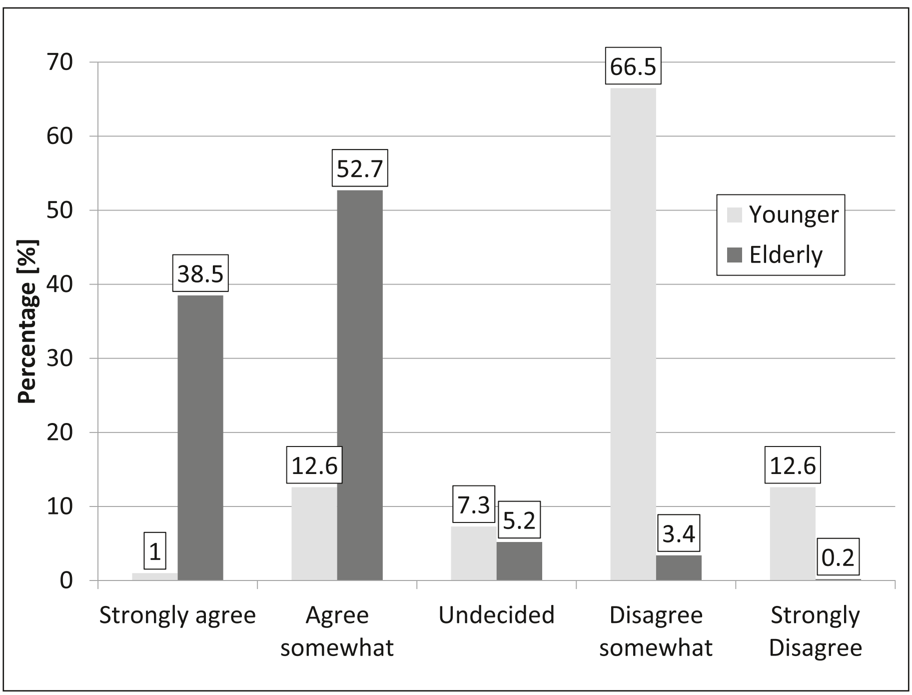

Figure 26: Distribution of answers to the question: Do you think that you (or, in the case of younger participants, "elderly") would notice by yourself ("themselves") age-related changes in ability that might endanger traffic safety? (Richter et al., 2010).

older drivers, Marottoli and Richardson (1998) found a correlation between the number of kilometres driven and self-assessment: the more kilometres elderly people drive, the higher they rate their driving ability.

The positive self-assessment of the elderly regarding their driving speed in comparison to both younger drivers and their own age group points in the same direction.

This contrasts with the somewhat negative image that young drivers have of older drivers (Richter et al., 2010). There are also significant differences concerning the possibilities of compensating for age-related deficits. Older drivers are convinced that they can compensate for age-related changes. However, only 30 % of younger drivers believe that older drivers are able to do this (Richter et al., 2010) (see Figure 26).

On the one hand, the positive self-image that older drivers have of themselves can have a positive influence on well-being and psychological health in old age. On the other hand, older drivers can end up in situations where they reach the limits of their abilities and there is an increased risk of an accident.

The development of values and motives over a lifetime together with the development of traffic-relevant personality characteristics (e.g. more tolerance and conscientiousness, less aggression) foster a positive driving style over the course of a lifetime (Herzberg, 2008). In addition, increased compliance and a rise in the need for safety in old age have a positive affect on driving style (Herzberg, 2008). However, if with increased age there is also an increase in reactance (old-age stubbornness), safe driving behaviour can worsen, for example, when traffic-relevant functional impairments are not taken into account by the person affected.

In summary, the development of personality characteristics and values that are relevant for traffic safety exert a positive influence on driving participation. Nevertheless, society as a whole should deal with age-related changes that are traffic-relevant in a sensitive and considerate way, so that they too can indirectly contribute to road safety.

7 Older drivers: Are they more at risk?

7.1 Accident statistics

Driving a car places a range of complex demands on resources such as perception, attention and motor skills. Based on the age-related changes described earlier, it can also be assumed that the risk of an accident also changes with age. Whether this is actually the case and to what degree are addressed in this chapter.

Looking firstly at the absolute figures for accidents, it would appear that older drivers do not represent an increased risk of accidents compared to other age groups. This is also the case when looking at risk based on a percentage of the population. In Germany, in 2010, 21 % of the population were aged over 65 years according to the German Federal Statistical Office. However, the percentage of people in this age group involved in accidents resulting in injury or death was only 11 % (Statistisches Bundesamt, 2011).

However, the ageing population as part of the demographic shift means that the number and percentage of seniors killed is rising. In Germany, the percentage of accidents involving drivers over the age of 65 years more than doubled from 4.7 % in 1990 to 11.8 % in 2011 (Statistisches Bundesamt, 2012b). The European Transport Safety Council (2008) also forecasts that the percentage of elderly people killed on European roads will rise from one-fifth to one-third by 2050.

A different picture arises when looking not at the number of accidents but the number of fatalities. In 2011, 4009 people were killed on German roads and of these 1044 were older than 65 years (Statistisches Bundesamt, 2012b). This represents 26 % of fatalities and as such is higher than 20 % which is their proportion of the population (Statistisches Bundesamt, 2013).

The trend for the total number of fatal accidents and the percentage of these accidents involving elderly drivers (Figure 27) is rather unfavourable for the aged (Statistisches Bundesamt, 2012b). Whereas only one in twenty accident victims was older than 65 years in 1991, by 2006 this figure had increased to one in ten (Schönebeck, 2007). In comparison, the percentage of accidents involving the risk group of young drivers aged 18-24 decreased.

This trend is similar across Europe. Data from the Care Database (European Commission, 2011b) for 19 EU countries shows that the decline in the percentage of deaths for people aged over 65 years is slower than for the total population (Figure 28).

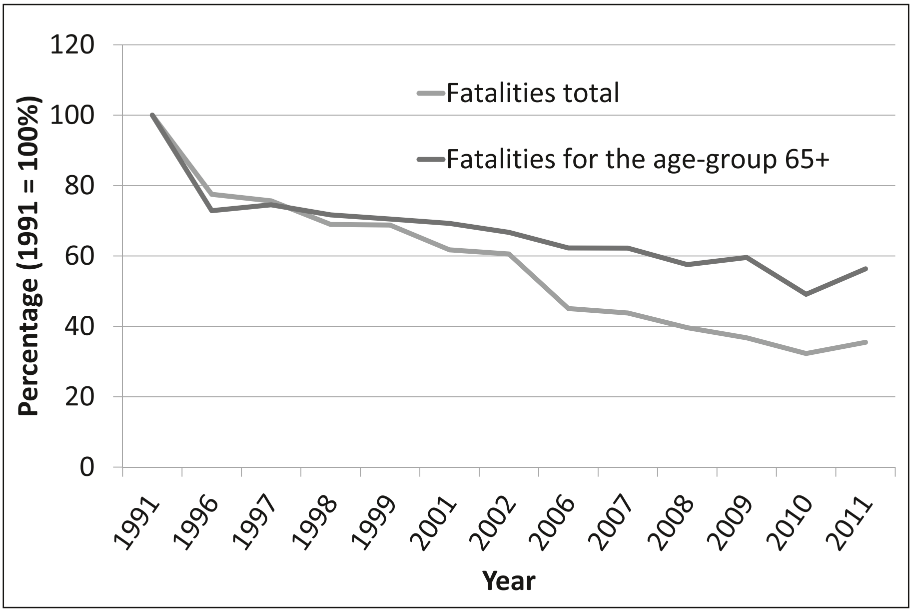

Figure 27: Percentage of older drivers killed in accidents in Germany from 1991-2000 (own calculation based on Statistisches Bundesamt, 2012b, 1991=100).

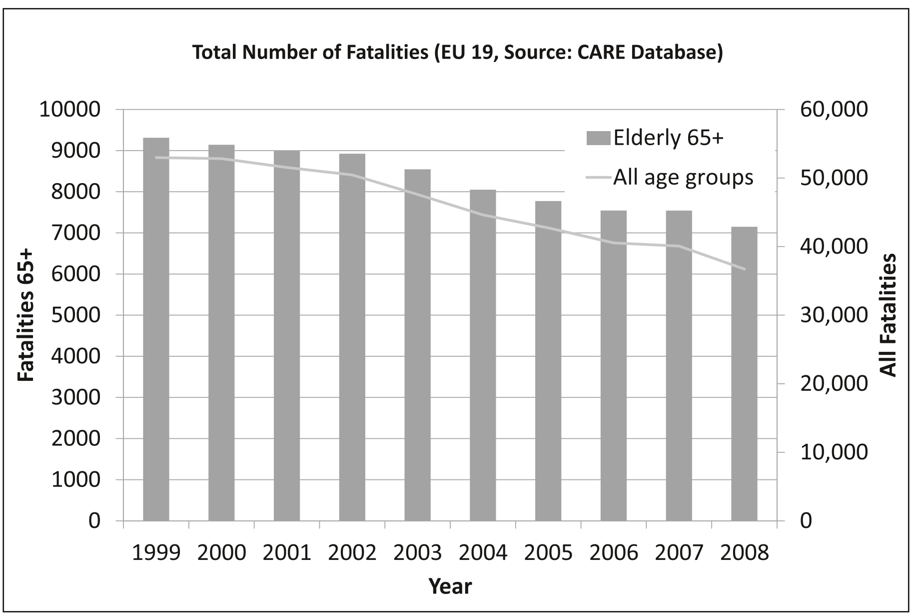

Figure 28: Fatalities of elderly drivers, progress 1999-2008. Base rate: 19 EU States (source: ERSO, 2011b, 2011c).

Looking at accident rates in relation to the percentage of licensed drivers in all age groups results in a “bathtub curve” (Shinar, 2007). This shows that drivers who have recently got their licence have the highest accident rate, this then drops with age and only increases again, albeit slightly, for people aged more than 65. It then increases significantly for drivers aged around 75 (Elvik & Vaa, 2004; Fildes et al., 2000; Shinar, 2007).

A similar picture can be seen when looking not at the percentage of licence holders but the percentage of kilometres driven. According to Evans (2001) this is the best predictor of accident risk, but likewise this only increases significantly from around the age of 75. Important to note is that the risk for drivers aged 65 years is still below that for novice drivers (Hargutt, Körner, Krüger, & Maag, 2007).

In this context, it is also interesting to see cohort effects. Studies in Norway and Sweden by Thulin and Bjornskau (cited in Elvik & Vaa, 2004), show that the risk of accidents has dropped slightly from year to year. The authors attribute this to the increase in driving experience as part of a heavily motorised society.

Figure 29 illustrates the bathtub function, once in terms of risk by licensed driver and once for the number of kilometres driven. It can be

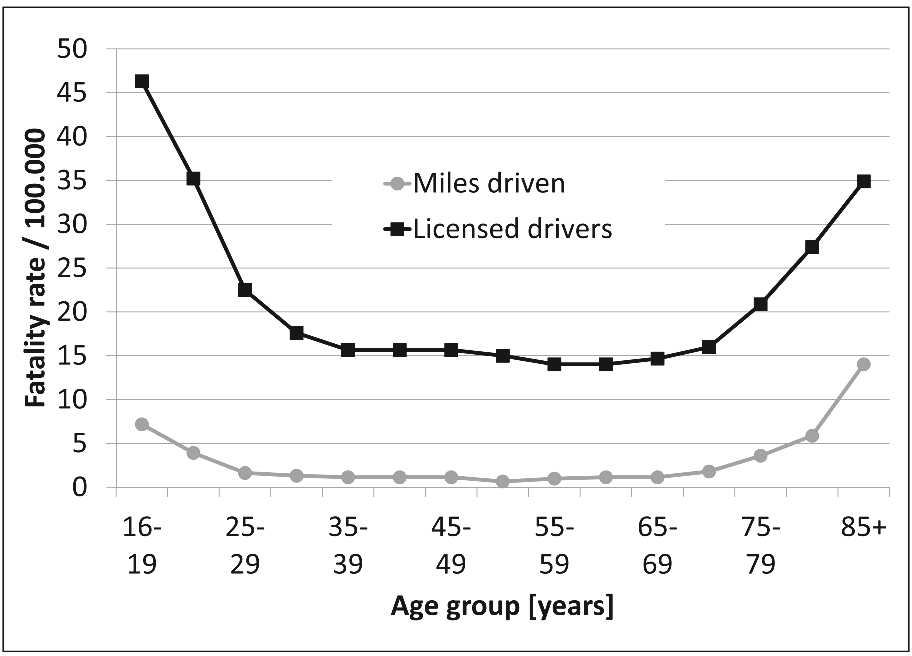

Figure 29: USA Motor vehicle fatality rates by age group (Eby & Molnar, 2009).

seen that the number of fatalities per 100,000 licenced drivers increases for both novice drivers and drivers over 65 years when compared to the age groups in the middle (Eby & Molnar, 2009). This indicates that these age groups have a higher risk of being involved in a fatal accident than middle-aged drivers.

Additionally, it should be noted that older people drive less and many do not drive at all anymore even though they still have their driving licence. Thus, calculating the number of fatal accident per mileage driven permits more detailed assertions. Such results have also been published by other authors (Loughran et al., 2007; S. Lyman et al., 2002; Massie, Campbell, & Williams, 1995; NHTSA, 2005).

Figure 30 shows the differences between age groups and between genders. The relative alignment of the risks for men and women between 35 and 65 years differs as dramatically for drivers aged over 85 years as it does for very young drivers.

New figures regarding age and performance related risk also show a marked increase in risk with age (Insurance Institute for Highway Safety (IIHS), 2012). At the same time, this study demonstrated a lower risk for younger drivers (see Figure 31). The reason for this could be the strategies that are specifically targeted at this younger age group. How-

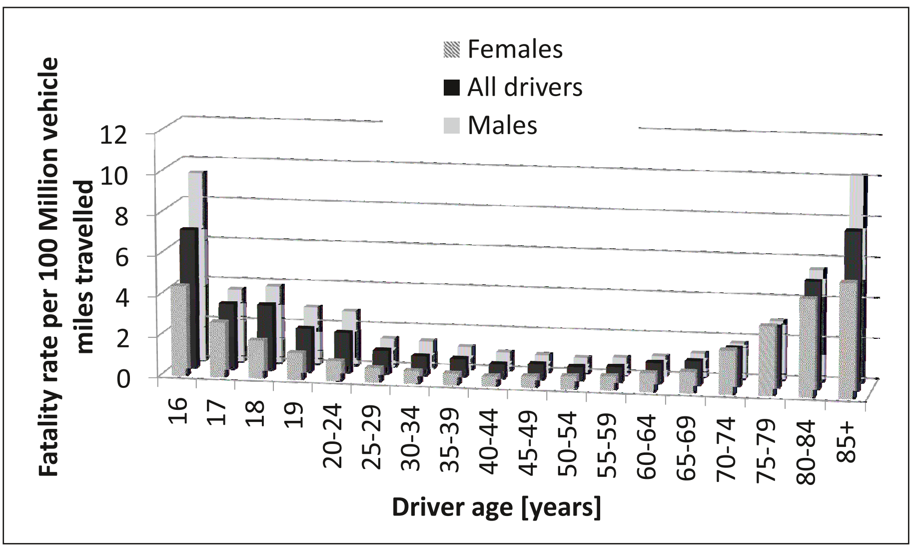

Figure 30: Driver fatality rates by age and sex, 1996 for the United States. Vehicle miles travelled are based on estimations. (source: NHTSA, 2005).

ever, methodological causes could also play a role (the data source for the number of kilometres driven).

The data from Figure 29 to Figure 31 support the assumption that drivers aged older than 75 are at increased risk of dying in an accident. This will be looked at more closely in the section concerning “Low-Mileage Bias” (see Chapter 7.2).

The data suggests that older drivers are involved in more accidents with serious injury or death than other age groups. Data from the German Federal Statistical Office (Statistisches Bundesamt, 2012b) shows the proportion of victims by age group and by severity (see Figure 32). This phenomenon is referred to as Frailty Bias in the literature (see Chapter 7.3).

Fatality rates reveal a different side of accidents involving older drivers. Compared to other age groups, older drivers usually represent a very small proportion of the total number of fatalities (Shinar, 2007). Possible explanations for this fact are given in the Chapters 7.2 and 7.3.

So far, two accident measures have been mentioned: the absolute number of accidents - which is not suited for risk analysis - and measures related to exposure. Exposure is usually defined as time or distance driven, separated by the age group under consideration.

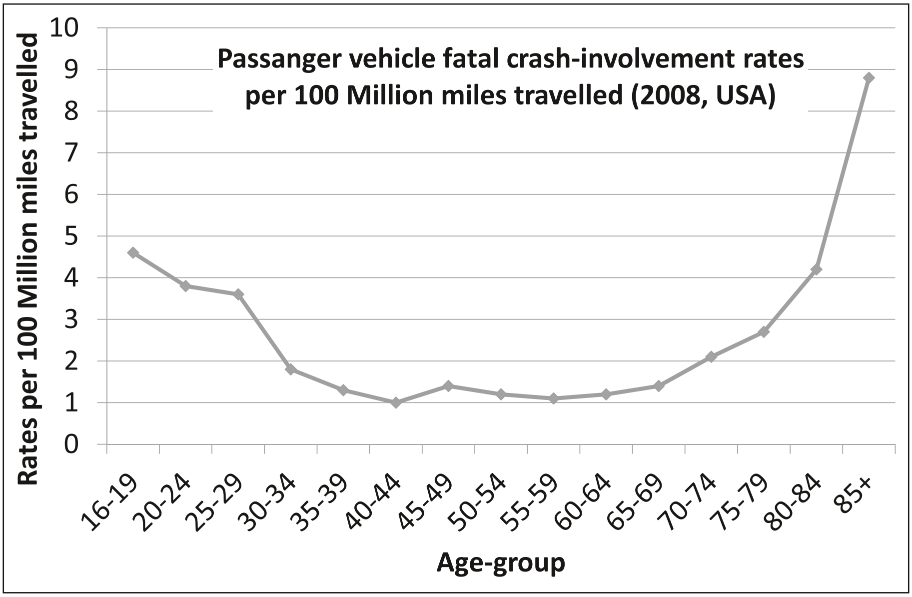

Figure 31: Passenger vehicle fatal crash involvement rates per 100 Million miles travelled (data for 2008, USA; source: IIHS, 2012).

However, the problem is collecting the exposure data. As Kirk and Stamatiadis state, “the lack of appropriate data on exposure is one of the greatest problems that road safety analyses have faced so far” (Kirk & Stamatiadis, 2001, p. 8). Whereas overall exposure (i.e. the kilometres driven) can be calculated from gasoline consumption, this is not so easy to do for specific groups of drivers. Exposure data for these groups is collected by using the number of licensed drivers per group, by telephone or other surveys, or by on-the-road observations (Joksch, 1973; Lenguerrand, Martin, Moskal, Gadegbeku, & Laumon, 2008). However, this is costly and can be unreliable.

Even if these kilometres could be reliably assessed, there are differences based on the conditions under which these kilometres were driven, for example, day or night, motorway or inner city (see also Chapter 7.2 “Low-mileage bias”). As such, using miles driven as a measure for exposure is at least accompanied by a critical discussion (Chandraratna & Stamatiadis, 2009).

A method which goes a step further is the use of case-control studies. These look at drivers who had an accident and the controls are other drivers who did not have an accident during the same time period and, depending on the study purpose, at the same or similar locations. The

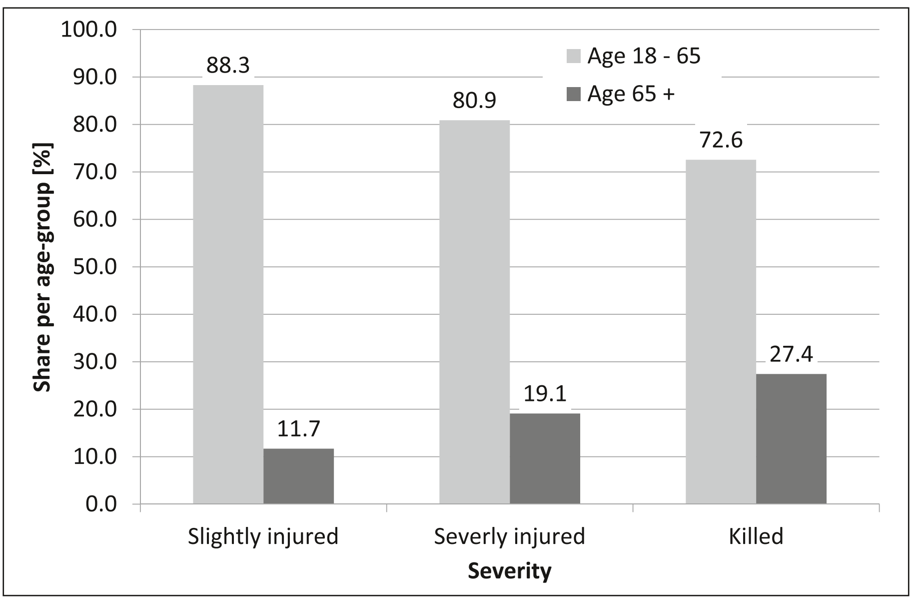

Figure 32: Accident severity: Proportion per age-group (data for Germany 2011; source: Statistisches Bundesamt, 2012b).

selection of controls is the critical step in case-control studies. Híjar, Pérez-Núñez, and Inclán-Valadez (2011) name seven basic principles for this step. However, a measure of exposure is once again needed in order to achieve reliable results.

To overcome these difficulties, a measure was developed which does not use actual exposure data but a surrogate or induced measure of exposure. This induced exposure is derived from accident involvement data: “The induced exposure approach involves using only accident involvement data, and from these data inferring, on the basis of certain assumptions, estimates of driver exposure -hence enabling statistics related to driver risk to be calculated.” (Cuthbert, 1994, p. 177).

This proxy or “induced” measure of exposure is based solely on accident experience and is contained exclusively in accident reports (Haight, 1973). This means that the aggregated accident data that is usually published by statistics departments cannot be used.

The quasi-induced exposure method introduced by Haight (1973, cited in Cooper, Meckle, & Andersen, 2010) additionally uses responsibility as a defining characteristic.

The basic rationale behind the quasi-induced exposure measure is that drivers involved in an accident are divided by their role in causing the accident. The case group are the drivers at fault and the control group are their not at-fault counterparts. Given that the drivers at-fault “select” their not at-fault “victims” by chance, it is assumed that “… the samples of not at-fault drivers are representative of the populations on the road at the time of the accident” (Méndez & Izquierdo, 2010, p. 582). The quasi-induced exposure method restricts itself to “clean” two-vehicle crashes in which one driver was declared solely responsible and the other driver was declared not at fault (Lenguerrand et al., 2008).

Due to the complexity of the quasi-induced exposure measure, it may be beneficial to look at a simpler statistic first. For the data shown in Figure 33 the percentage of at-fault drivers per age group was calculated (Statistisches Bundesamt, 2012b). This was mainly done to illustrate the differences to the quasi-induced exposure method. Figure 33 shows that very young drivers and very old drivers have an increased rate of being culpable compared to drivers 35 to 55

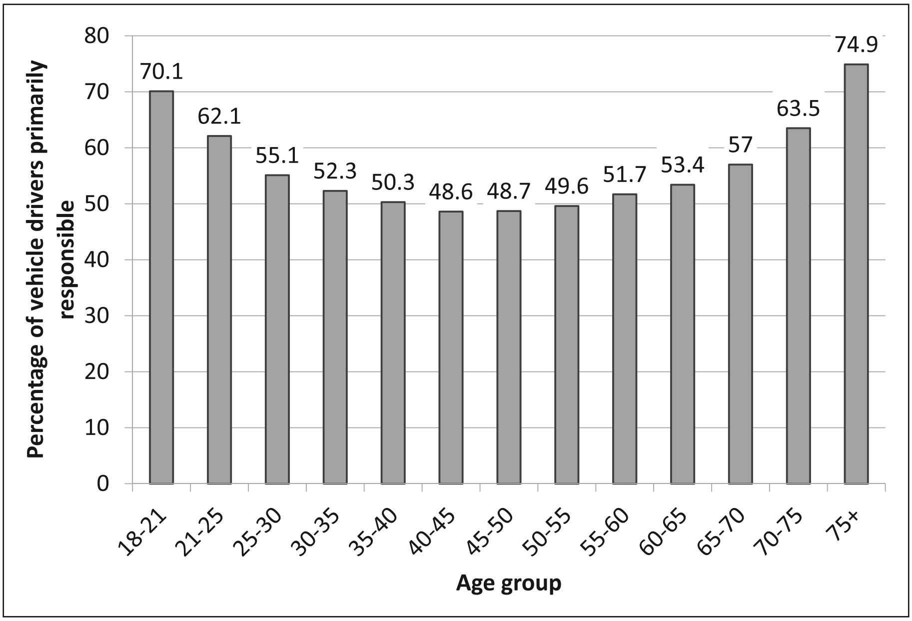

Figure 33: Percentage of car drivers at fault per age group in accidents with personal damage in Germany 2011 (source: Statistisches Bundesamt, 2012a).

years old who were culpable in less than 50 % of the cases. Nevertheless, Figure 33 is interesting in itself because it differs greatly from the quasi-induced exposure method due to the fact that exposure is not taken into account. Figure 33 is only based on aggregated data, that is, no individual accident was analysed. For the quasi-induced method each accident must be analysed for its suitability for the analysis.

The data shown in Figure 33 and the information needed for quasi-induced exposure do have one thing in common: they are both based on the culpability-data. Thus, the validity of these culpability data must be discussed.

Although it is often claimed that police are biased against very young and very old drivers in their decision of who is to blame, no evidence could be found for that claim (Shinar, 2007). Therefore, within the limitations of human decision making, police records can be considered as a reliable source for inferring accident culpability.

Another aspect is related to single vehicle accidents. In Germany the main person responsible for an accident (German: “Hauptverursacher”) is defined as “…the person who in the opinion of the police is chiefly to blame for the accident. Road users involved in single-vehicle accidents are always regarded as mainly responsible." (Statistisches Bundesamt, 2012a, p. 32). This has an implication for the calculation insofar as quasi-induced exposure is usually based only on two vehicle accidents (which are further characterised by one party being solely to blame). In contrast, the data shown in Figure 33 includes single vehicle accidents. Given that older drivers are underrepresented in single vehicle accidents, their high value in Figure 33 can likely be attributed to errors resulting from their declining abilities.

As already indicated the calculation of a quasi-induced exposure measure is somewhat more complicated. Based on information regarding who is to blame the "Relative Accident Involvement Ratio" (RAIR) or "Crash Involvement Ratio" (CIR) can be calculated "by taking the ratio of the percentage of at-fault drivers in a specific subgroup to the percentage of not-at-fault drivers from the same subgroup" (Kirk & Stamatiadis, 2001, p. 8). Thus, the responsible drivers in the enumerator of the equation act as cases and the non-responsible drivers in the denominator act as controls and a measure of exposure.

The Relative Accident Involvement Ratio for a certain driver or vehicle type i and for two (or m = multi) vehicle crashes is (Lardelli-Claret et al., 2006)

$$RAIR_{i/m} = \frac{P_{i/r}}{P_{i/nr}}$$

where:

$P_{i/r}$ = proportion of type i drivers in the group of drivers responsible for two-vehicle crashes

$P_{i/nr}$ = proportion of type i drivers in the group of drivers not responsible for two-vehicle crashes.

Lardelli-Claret et al. (2006) and Lenguerrand et al. (2008) state that a slightly adapted formula can also be used for single vehicles, provided that the risk of being involved in a single vehicle accident is comparable to the risk of being involved in a two vehicle accident (see also Stamatiadis & Deacon, 1997). In this case, the responsible drivers of the single vehicle accidents are compared with the non-responsible drivers in two-vehicle accidents.

An odds ratio (OR) can be calculated for both single-vehicle and two-vehicle accidents in order to compare the risk of one group i with a reference group k. For two vehicle crashes, both RAIR are used to calculate the OR as:

$$\frac{RAIR_{\frac{i}{m}}}{RAIR_{\frac{k}{m}}} = \frac{\frac{P_{\frac{i}{r}}}{P_{\frac{i}{nr}}}}{\frac{P_{\frac{k}{r}}}{P_{\frac{k}{nr}}}} = OR_{i/m}$$

Figure 34 shows a graph resulting from a quasi-induced calculation for two-vehicle accidents. The data for this graph comes from accidents in the United States for the five year period 2002 to 2006 taken from the Fatality Analysis Reporting System (FARS) and the National Automotive Sampling System (NASS)/General Estimates System (GES).

It can be deduced from Figure 34 that the risk of causing an accident is lowest for the age group 30 to 69 and dramatically increases for the age group 80+ (Stutts, Martell, & Staplin, 2009).

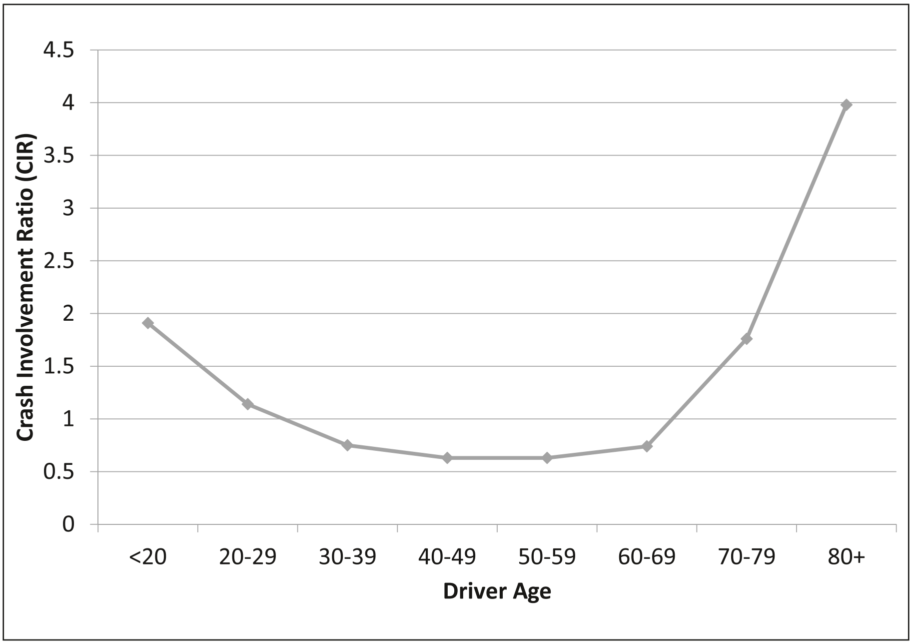

Figure 34: Crash Involvement Ratio (CIR) for all two-vehicle fatal crashes by driver age (Stutts et al., 2009).

7.2 Low mileage bias

It is often said that older drivers are at increased risk of a crash due to the impairments mentioned earlier. This association has been supported by analyses of crash data for older and younger drivers. These show a higher crash risk for both the elderly and the younger drivers when the number of accidents is referenced to distance or time driven, resulting in what is known as the bath-tub function (Schade, 2000) (see also Figure 35).

A closer look at the data reveals that drivers aged 60 to 64 years are not at increased risk of being involved in accidents. In contrast, the risk of being involved in an accident is three times higher for young drivers when compared to this age group. From the age of 75 years onwards the statistical accident risk increases slowly and then increases sharply from the age of 85 years (Loughran et al., 2007).

However, these data have not taken into account two modifying aspects:

- the effect of increased frailty in the elderly on accident data ("frailty bias"),
- the effect of low mileage on accidents ("low mileage bias").

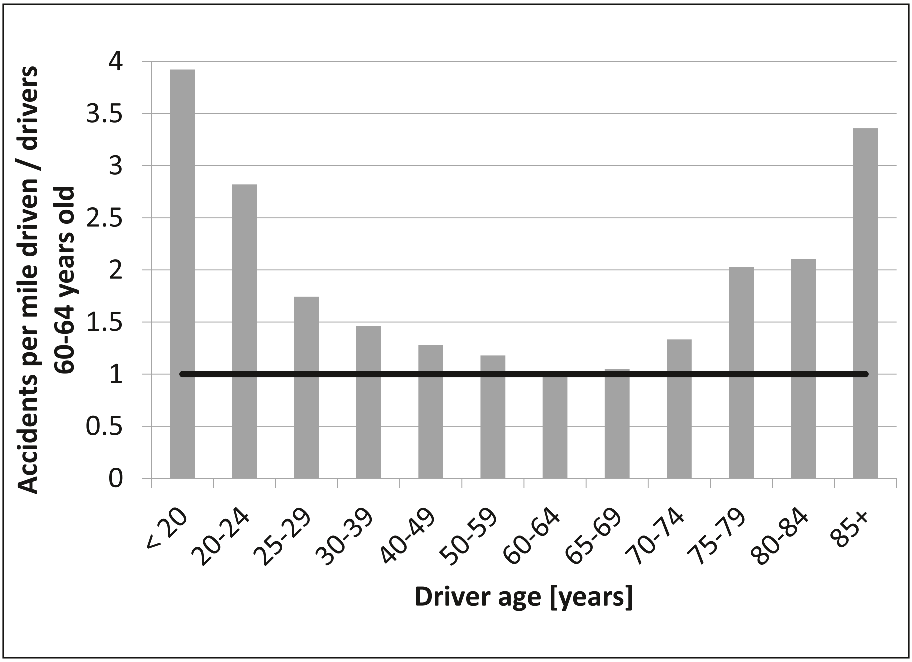

Figure 35: Accidents per mile driven by driver age (Loughran et al., 2007).

The first effect describes the fact that the risk of being injured in an accident increases with age. The bias in accident statistics is caused by the fact that noninjury accidents are underreported by the police (Loughran et al., 2007). If no information on blame is available these effects suggest a higher risk for older drivers than might actually be the case. The second effect is based on a finding by Janke (1991) which showed that drivers who travel fewer miles/kilometres have higher crash rates because local roads are inherently more dangerous due to more interactions with other traffic. Hakamis-Blomqvist, Raitan, and O' Neil (2002) later termed this finding the ”low mileage bias”.

In other words: driver groups with a low annual driving exposure, such as older drivers show higher accident rates than driver groups with a high annual driving exposure (Hakamies-Blomqvist, Raitanen, & O'Neill, 2002). Based on Janke's finding, Hakamies-Blomqvist et al. (2002) analysed the accident rates of older and younger drivers in more detail. They did not find an increased crash risk for older drivers if kilometres driven per year were taken into account (Figure 36).

Langford, Methorst, and Hakamies-Blomqvist (2006) matched older and younger Dutch drivers with a similar driving exposure per year and found evidence that elderly drivers were as safe as or even safer than younger drivers. In conclusion, the age-related higher risk of elderly

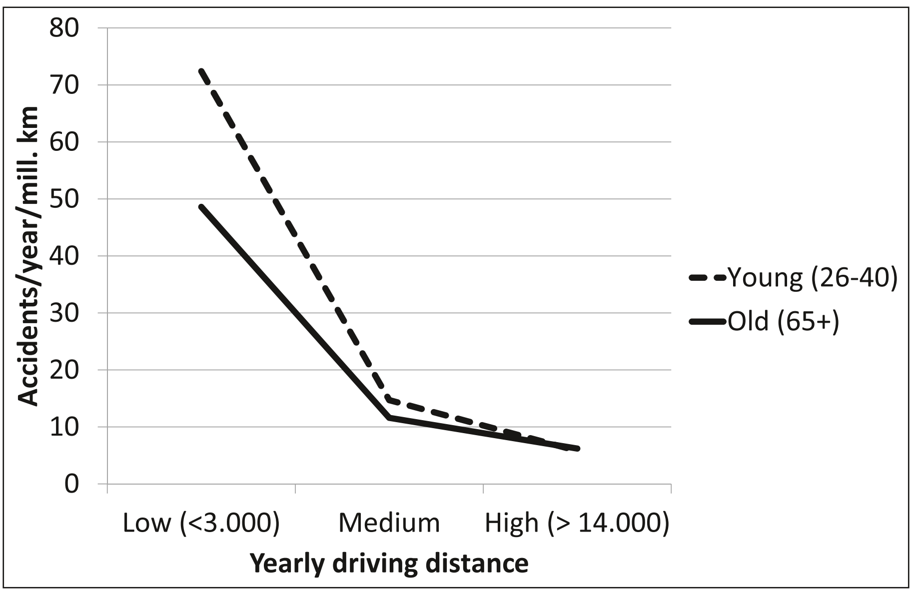

Figure 36: Yearly driving distance and accidents per km by age group (Hakamies-Blomqvist et al., 2002).

drivers is also influenced by the lower yearly driving distances of this age group. These results are supported by findings from Fontaine (2003) and Langford, Methorst, and Hakamies-Blomqvist (2006).

The low-mileage bias suggests a higher crash risk for elderly drivers, because they tend to drive less, the older they are (Figure 37).

Does this mean that drivers in general should drive more or longer distances in order to reduce their risk per distance driven? Leaving aside ecological issues, the answer to this question is “yes”. However, the answer to the question is less clear when solely applied to elderly drivers. This is because driving less is in itself a strategy to compensate for an age-related decline in driving ability. In fact, it is a successful strategy, because - by driving less - risk is reduced – as long as it is not referenced to distance or time driven.

In practice, there must be a compromise between driving more to maintain driving skills and driving less once drivers feel unsafe. Restricting driving to well-known territory might be such compromise.

In order to provide a balanced view the weak points of the low-mileage theory must also be mentioned. Critics of the low-mileage bias mention the use of self-reporting data, which is subjectively biased (Langford,

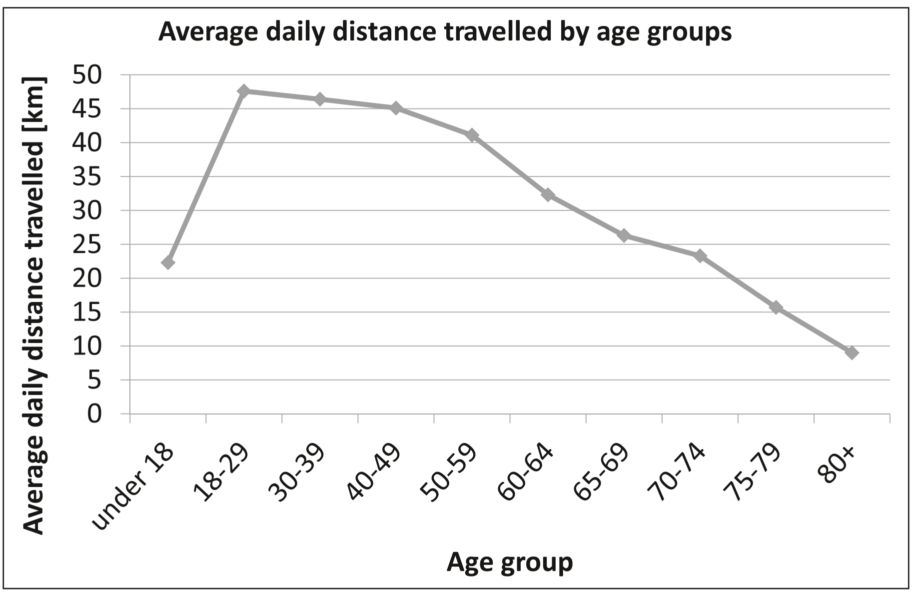

Figure 37: Average daily distance travelled [km] by age groups in Germany (source: BMVBS, 2010).

Koppel, McCarthy, & Srinivasan, 2008; Staplin, Gish, & Joyce, 2008). Thus, to confirm the findings further, it is necessary to use an objective measure for distance driven, such as odometer readings (Langford et al., 2008).

7.3 Frailty bias

Part of the reason why older drivers are overly involved in serious injury crashes is their increased frailty and hence vulnerability to injury (Oxley, Fildes, Corben, & Langford, 2006). The frailty bias describes the increased risk of being injured more seriously in traffic accidents with advanced age. Compared to younger drivers, older drivers are more often seriously injured or even die in accidents of the same impact (Skyving, Berg, & Laflamme, 2009).

Different factors can explain this fact. The first explanation deals with the different accident types. The cognitive and visual impairments of older drivers make them especially prone to turning accidents which can result in more severe injuries (Bédard, Guyatt, Stones, & Hirdes, 2002). Other reasons are a higher likelihood of fractures and chest injuries and a general age-related decline in physical health (Li et al., 2003; Schade, 2000; Welsh, Morris, Hassan, & Charlton, 2006).

However, it is not that easy to tease apart the factors responsible for this overrepresentation in accidents involving serious injury or death. Is this due to age-related frailty, the mileage driven or increased risk because of driving style or errors? Li, Braver, and Chen (2003) made an effort to do this by analysing different risk types of different age groups. First of all, they found the highest death rates per vehicle mile of travel (VMT) for the youngest drivers aged under 20 years and elderly drivers aged 75 years and above, with a further increase from the age of 80 years onwards. When relating this finding to other risk indices they found that the over-involvement of both the younger and older drivers is due to an overrepresentation in accident involvement, but it is further compounded by frailty in the older age groups (Schade, 2000).

An Australian study showed that frailty doubles the number of serious injury crashes per billion kilometres from the age of 70 onwards (ATSB, 2001, cited in Fildes, Oxley, Corben, & Langford, 2004). Although it is clear that frailty disproportionally adds to the number of fatalities amongst elder people, their number is still higher than for middle-aged drivers but still lower than for the youngest age group (see Figure 38).

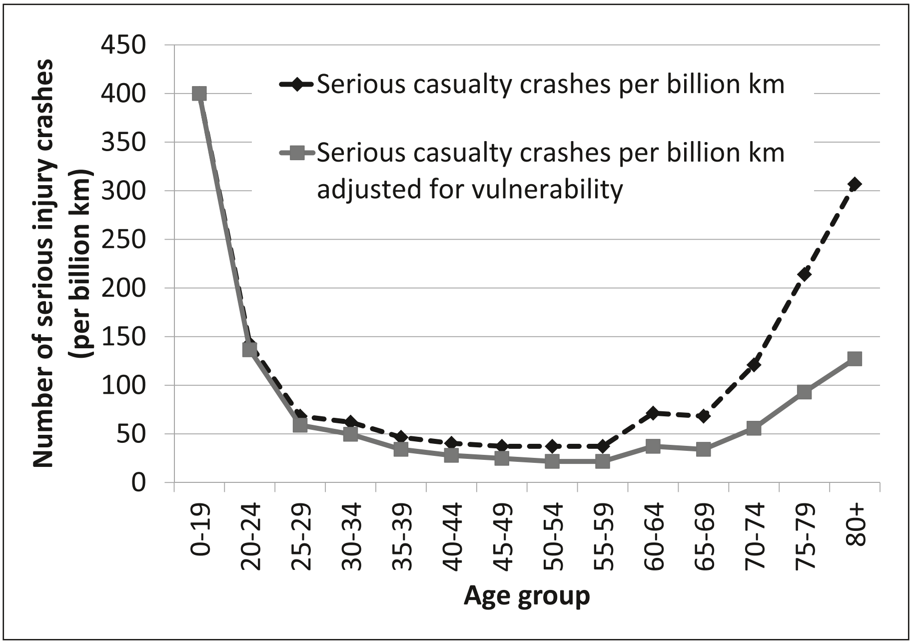

Figure 38: Rate of serious casualty crashes in Australia by age group 1996 (ATSB, 2001, cited in Fildes et al., 2004).

In terms of the risk that older drivers pose to other traffic participants, one has to note that it is more the older drivers themselves who are at risk because their frailty means they are more severely injured than the other participants. However, because older drivers often travel together with older occupants, the injury and death rate of accidents with an older driver usually is also higher, again owing to frailty bias.

The result of frailty bias is that older drivers are regarded as being more dangerous and being at more danger than they actually are. This is because non-injury accidents are underreported by the police (Loughran et al., 2007). If information on blame is also unavailable or is disregarded, a higher risk for elder drivers is suggested than is actually the case.

In Figure 32, which shows data for Germany (Statistisches Bundesamt, 2012b), it can be seen that the proportion of older drivers rises with increasing severity. Figure 39 gives a more detailed picture. It is based on data from different sources that were combined by Maier et al. (2012). It can be seen that besides physical frailty other factors must also play a role. The fact that younger drivers aged 18-25 show the highest injury rates (Figure 39) can be a combination of two factors: the general increased risk of younger people and the fact that they usually drive older and thus less safer cars (Keall & Newstead, 2013). However,

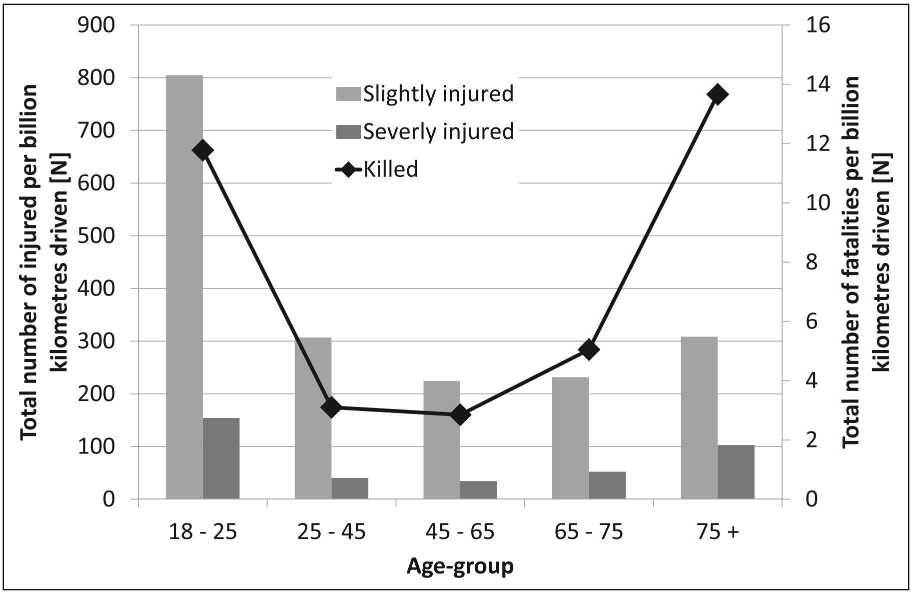

Figure 39: Accident severity for different age groups per kilometres driven (data for Germany 2006, based on Maier et al., 2012).

the fact that drivers aged 75+ are overrepresented is probably indeed an indication of their physical frailty.

Data from Great Britain (Baster, 2012) on people injured by busses or trains also shows that older age-groups are more prone to injuries regardless of whether they caused the accident or not.

8 Details of older drivers' accidents

A model helps provide a structure to the topic of dealing with accidents. Figure 40 shows such a model. It is based on various sources (Fuller, 2005; Reichart, 2001; Schlag, Nirschl, Weller, Böttcher, & Voigtländer, 2005) and was enhanced to incorporate traffic offences and preceding factors leading to errors and offences.

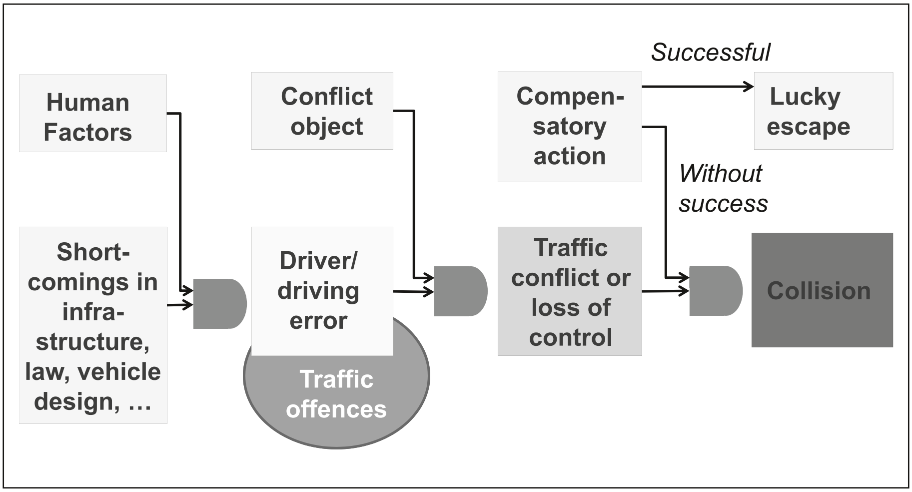

Figure 40: Generic error and accident model (source: SaMERU, 2013).

The model reflects the belief that collisions are the effect of the preceding factors that can be eliminated or modified in a way so as to be no longer dangerous. In this sense accidents do not happen by chance (or "by accident") but are the visible outcome of a chain of events often unnoticed until it is too late (Hollnagel, 2004). Therefore the term "collision" rather than "accident" is used in the model although the word "accident" will be used further in the report to reflect its ongoing popularity in the literature.

8.1 Causes of older drivers' accidents

Older drivers have difficulties, particularly in complex driving situations. Accident data from the German Federal Statistical Office (Statistisches Bundesamt, 2012a) indicate that elderly drivers predominantly make right-of-way errors and mistakes in turning. In contrast to drivers aged 18-21, elderly drivers show less than half as many offences related to inadequate driving speed that lead to an accident (Figure 41).

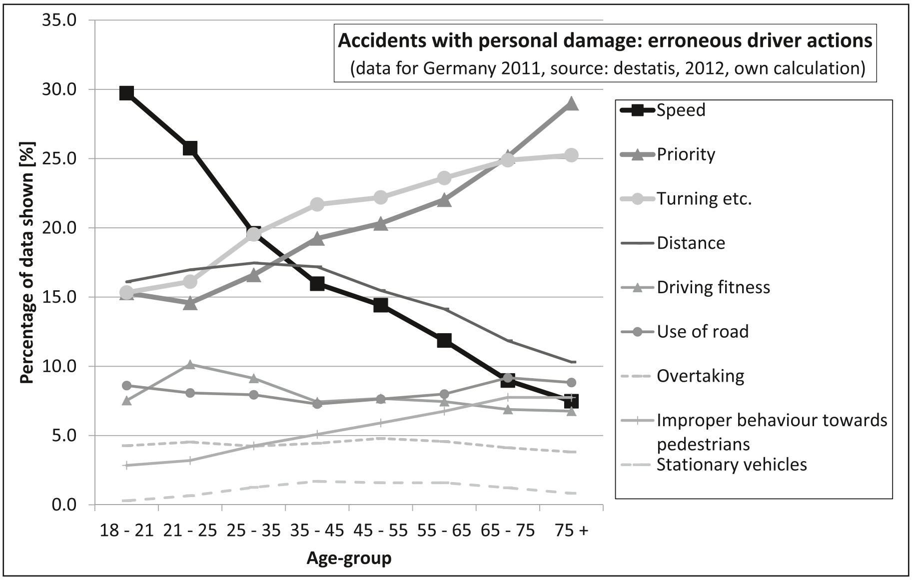

Figure 41: Different erroneous driver actions leading to accidents by age (source: Statistisches Bundesamt, 2012a).

Regarding traffic offences older drivers show fewer violations, such as exceeding the speed limit or driving under the influence. However, they have more offences related to driving errors. Such offences increase with age especially when referenced to mileage driven and when compared to younger drivers (Schade, 2000, 2008). Based on data provided by the German Federal Statistical Office (Statistisches Bundesamt, 2012a) (see Figure 41) manoeuvers such as turning are particularly the cause of accidents involving older drivers.

When data is analysed concerning who is primarily to blame for accidents with personal damage, it is very young and very old drivers who are mainly held responsible. Data shows that drivers aged 75+ are the group that, with a percentage of around 75 %, has the highest percentage of drivers being primarily blamed (see Figure 33).

In any case new, complex and potentially dangerous situations seem to cause uncertainty especially among older drivers. This leads to a shift from automatic processing of information to controlled and conscious processing which is error-prone (Summala, 1988).

8.2 The effect of location

8.2.1 Urban and non-urban roads

The majority of accidents and slight injuries happen inside urban areas. This is because of the high traffic density and the numerous conflict points present.

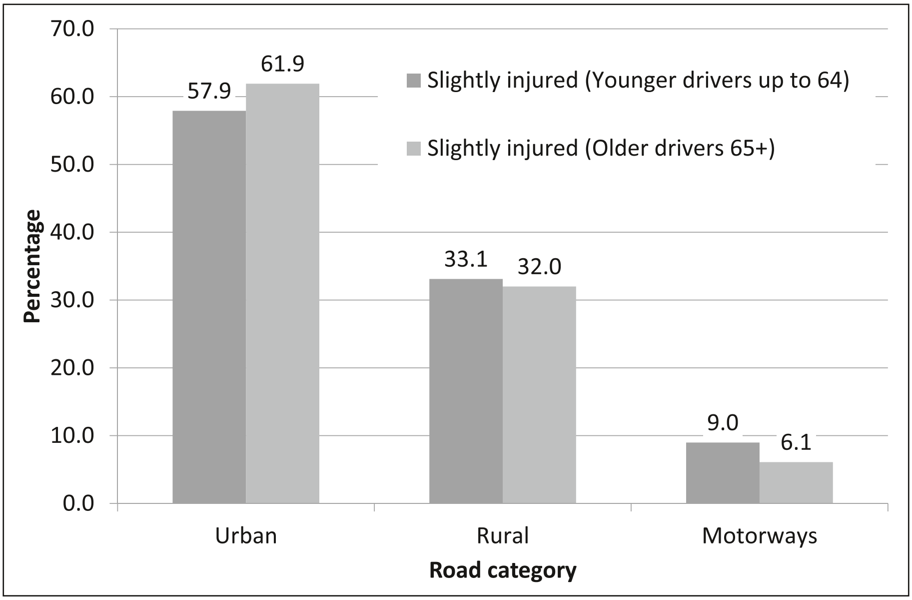

Figure 42: Slightly injured drivers in Germany 2011: Percentage by road category and age group (own calculation based on Statistisches Bundesamt, 2012a).

In contrast, rural roads (excluding motorways) are the most dangerous road category when looking at the number of fatalities. This is because of the inherent properties of this road category (Weller, 2010):

- the often historical roots and the fact that the geometry of rural roads often fails to meet current safety standards;
- the different functions these roads have to fulfil;
- the comparatively high speed limits and high speeds driven;
- the large variation of speeds driven, both within and between users; and
- the unforgiving roadsides.

This can be seen in the data shown in Figure 43 and Figure 44. In both figures a slight trend is visible when looking at the data for the older drivers in comparison to the younger drivers: the older drivers have a slightly higher percentage in urban areas and a respectively lower percentage on rural roads when compared to younger drivers.

This is also reflected in the crash involvement ratios (CIR) for two-vehicle crashes calculated by Stutts et al. (2009) (see Figure 44).

However, when analysing accident data provided by the European Commission (European Commission, 2012a, 2012b) and when calculating

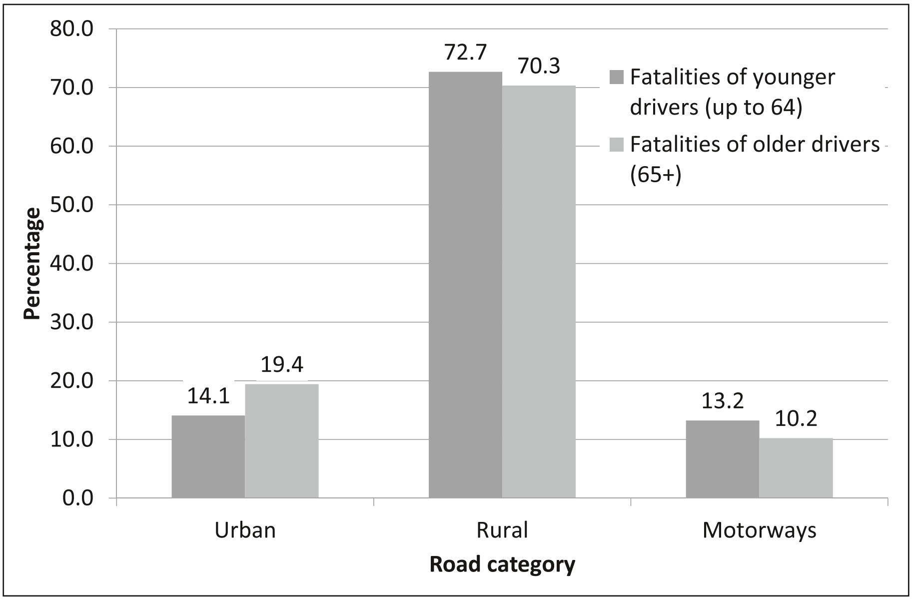

Figure 43: Fatalities for vehicle drivers in Germany 2011: Percentage by road category and age group (own calculation based on Statistisches Bundesamt, 2012a).

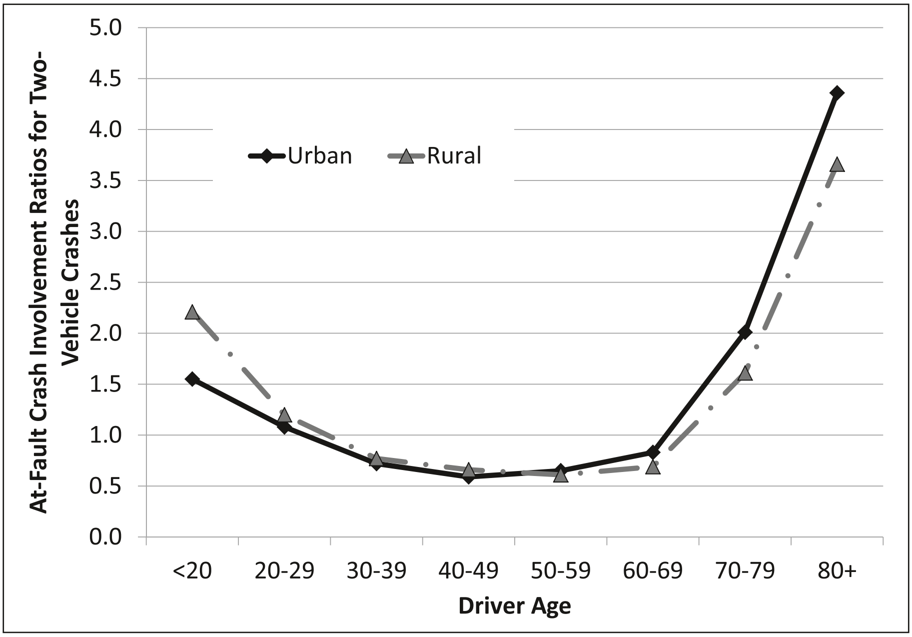

Figure 44: Two-vehicle fatal CIRs on urban versus rural roads based on FARS data (Stutts et al., 2009).

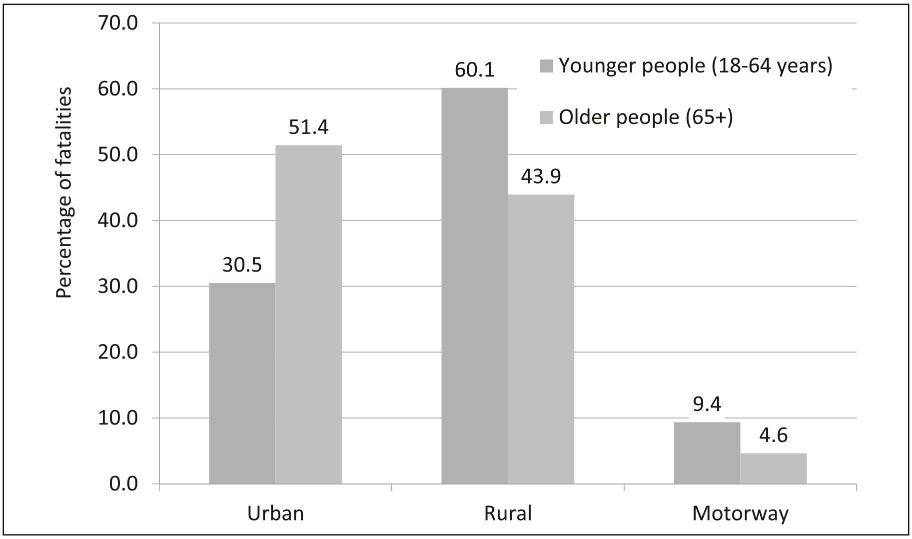

Figure 45: Percentage of fatalities on different road types for younger and older drivers in 21 member-states with motorways in the European Union (European Commission, 2012a, 2012b).

separate figures for younger and older fatalities a different picture arises. The main reason for the difference is the data sources: the data above is based on drivers whereas the data by the European Commission is based on all road users.

As can be seen in Figure 45[2] most fatalities involving older people do not happen on rural roads, as is the case for the younger age group, but rather on urban roads. The reason for this is certainly the different mobility pattern of older people (Institute of Advanced Motorists (IAM), 2010; Schlag, 2008c): older people travel shorter distances and thus travel more inside urban areas and on local roads. In addition, more trips are made on foot or by bicycle which additionally adds to the higher per-se vulnerability of older people (see Chapter 7.3).

Thus, when analysing the effect of location, that is, of differences between different road categories (urban, rural, motorways), one needs to take special care which figures to look at. The results for these analyses vary considerably depending on accident severity and mode of travel. This is reflected in the measures needed to increase the safety of older people. While in general, rural road safety needs to be tackled urgently to increase the safety of the entire driving population, older people would particularly benefit from measures inside urban areas.

2 For the data shown in Figure 45 only those 21 member states of the EU were selected that have motorways.

8.2.2 Intersections

The likelihood of a fatality being at an intersection increases with age and reaches nearly one third of all fatalities for drivers aged 65 years and above (see Figure 46). Data from the United States shows that this proportion increases to more than 40 % for drivers aged 85 years and above (IIHS, 2012). Based on FARS data of the Unites States between 2002 and 2006, Stutts et al. (2009) found that "over half of all fatal two-vehicle crashes involving drivers 70+ occurred at intersections" (p. 10). The crash involvement ratio in two-vehicle crashes at intersections increases dramatically from the age of 70 onwards (Stutts et al., 2009).

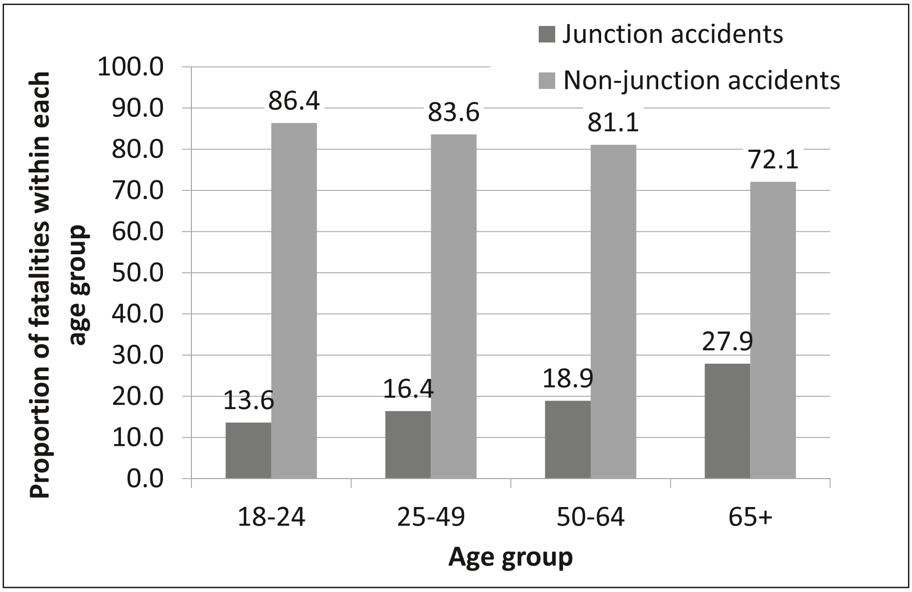

Figure 46: Proportion of fatalities per age group for EU-19, data for 2009 (own calculation based on ERSO, 2011a).

These fatality rates are mirrored by a high proportion of priority and turning accidents (see Figure 41). In general, the reason for the high proportion of intersection accidents is the result of intersection characteristics (high density of information and potential conflicts, time-critical decision making and action) and the reduction in sensory, cognitive and motor abilities of older drivers.

Detailed analyses show that it is particularly left turning (right turning for left hand driving countries) that poses a risk of a crash involving older drivers (Chandraratna et al., 2002; Chandraratna & Stamatiadis, 2003; FHWA, 1995; Gerlach et al., 2007; Institute of Advanced Motorists (IAM), 2010; Shinar, 2007) (see Figure 47 and Figure 48).

While drivers aged 60 to 69 years are only slightly overrepresented in left-turn crashes, the percentage doubled to 20 % for drivers aged 70 to 79, and increased up to 32 % for the 80+ drivers (Stutts et al., 2009).

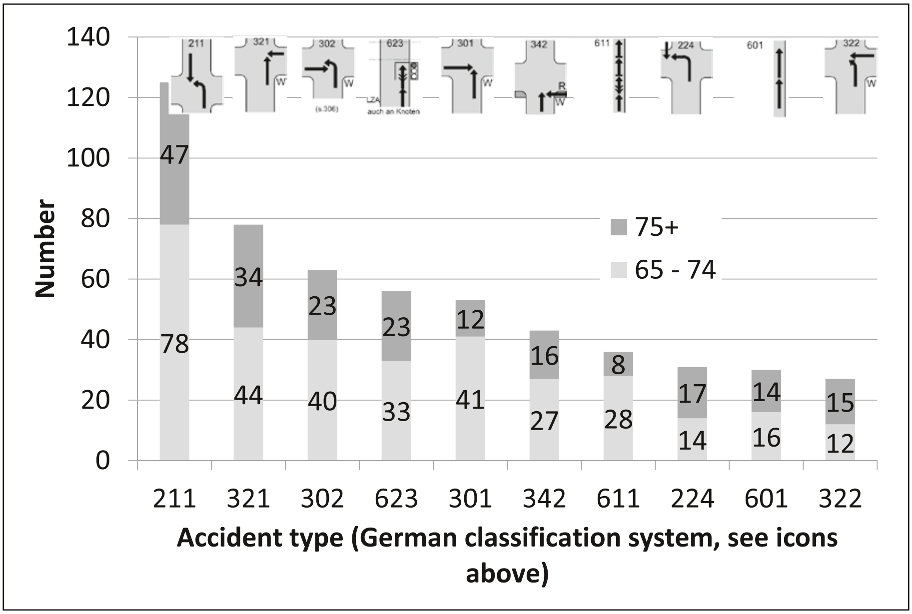

Figure 47: Most frequent accident types in accidents with personal damage and older drivers being the responsible party (Boenke & Gerlach, 2011b; Gerlach et al., 2007).

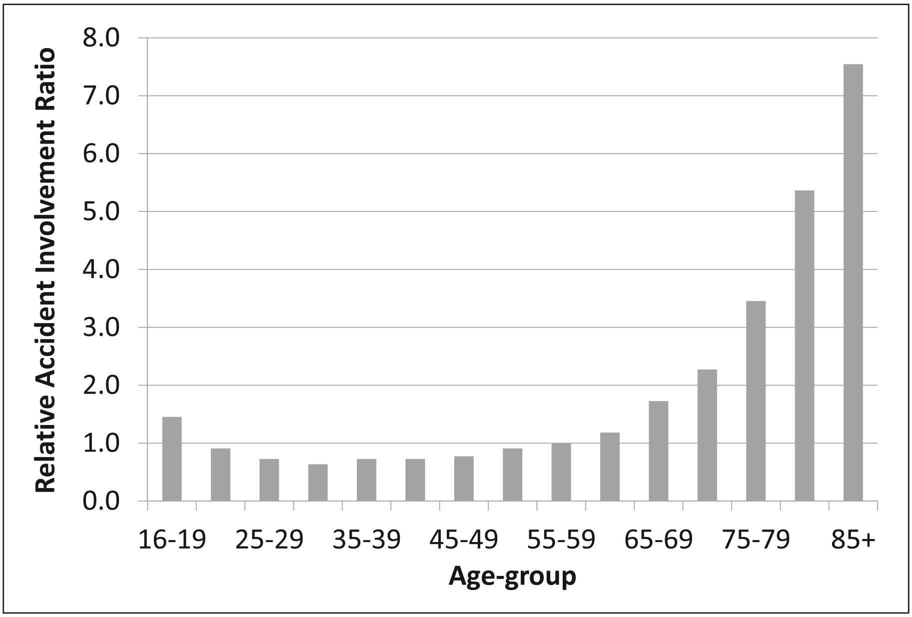

Figure 48: Relative accident involvement ratio for left turn crashes by age group (Chandraratna, Mitchell, & Stamatiadis, 2002).

In particular, the risk of having a fatal multi-vehicle accident at an intersection is 2.26 times more likely for drivers aged 65-69 and 10.62 for drivers aged 85 years and older, both compared to younger drivers aged 40-49. The corresponding figures for non-intersection-situations are 1.29 for drivers aged 65-69 and 3.74 for drivers aged 85+ (Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998). It is especially the drivers aged 85+ who are at risk in intersection accidents. These induced exposure figures were calculated based on FARS data for 1994 to 1995 as relative risk according to (see also Chapter 7.1):

$$Relative\ risk\ = \frac{T_f A_{nf}}{T_{nf} A_f}$$

where:

T_f = number of at-fault crash involvements for the target-age drivers

A_{fn} = number of not-at-fault crash involvements for the comparison or base-age drivers (here: drivers aged 40-49)

T_{fn} = number of not-at-fault crash involvements for the target-age drivers

A_f = number of at-fault crash involvements for the comparison or base-age drivers.

At first glance it is surprising that the authors found that going straight was associated with a much higher relative risk for older drivers than turning left. This is the case although "… about 40 % of the intersection crashes of drivers aged 75 and older involved left turns, compared with 7 % for 40-49 year olds" (p. 158). The reason for this seeming inconsistency is that all drivers, irrespective of age, were assigned fault when having had an accident while turning left. This fact results in a comparatively minor increase in relative risks for older drivers when compared to younger drivers.

Mayhew, Simpson, and Ferguson (2006) published a review of studies on older drivers` accidents in the USA and Canada since 1990, including the aforementioned study by Preusser et al. (1998). The reviewed studies confirmed the overrepresentation of older drivers in intersection collisions. Again, it is turning crashes in particular where older drivers are overrepresented. Their risk of being involved in such crashes was found to be typically two to three times higher than for younger drivers and was found to increase with age.

Mayhew et al. (2006) cite two studies (Chandraratna et al., 2002; Fildes et al., 2000) that found that the problems of older drivers at intersections are associated with problems in gap selection. Such problems in gap-selection are also named in studies by Oxley et al. (2006) and by Chandraratna and Stamatiadis (2003) as the most important problem when turning across or crossing traffic at intersections.

Although intersections pose a risk for older drivers, there are differences depending on the intersection design and on the right-of-way regulation. Boenke and Gerlach (2011a) found that especially intersections without traffic lights pose the greatest risk for older drivers. However, even if there are traffic lights, they must be designed to allow protected left turns to be effective.

In a field study with 62 drivers of different age groups Gstalter and Fastenmeier (2010) and Fastenmeier and Gstalter (2008) calculated error indices for each age group at different intersection designs based on the SAFE method (Fastenmeier & Gstalter, 2007). They found that turning (either left or right) was associated with a higher error index compared to going straight across a signalised intersection. Interestingly, higher error indices for older drivers were also found at a roundabout, confirming again that roundabouts do not result in fewer errors but in accidents of a lesser severity.

When calculating CIRs for different situations, Stutts et al. (2009) also found large differences depending on the design of the right-of-way regulation. Again, traffic signals are the safest way to design intersections (see Figure 49).

What are the reasons for the intersection accidents? Langford et al. (2005, cited in Shinar, 2007) analysed differences of intersection and non-intersection accidents: At intersections, the reason for an accident was more often that signals or signs were not seen and other traffic participants were overlooked. Braitman, Kirley, Ferguson, and Chaudhary (2007) and Mayhew et al. (2006) also found that the typical reasons were disregarding the traffic signals and failing to yield the right-of-way, particularly at stop-controlled intersections and when turning left.

Preusser et al. (1998) found further interesting facts when analysing the data: the main problem of older drivers was running a traffic control device such as traffic lights or stop-signs. Running stop signs and signals and disregarding yield signs were also found by Schlag (1994, 2003) to be the main reason for older drivers` accidents at intersections. In all cases, including turning, the main impact area when crashing is the vehicle side, and for fatal crashes particularly the left side. This difference in impact location might also explain the differences between analyses based on all accidents versus based on fatal accidents only: when turning left, the impact location will likely be the right side of the vehicle, thus, reducing the likelihood of a fatal accident.

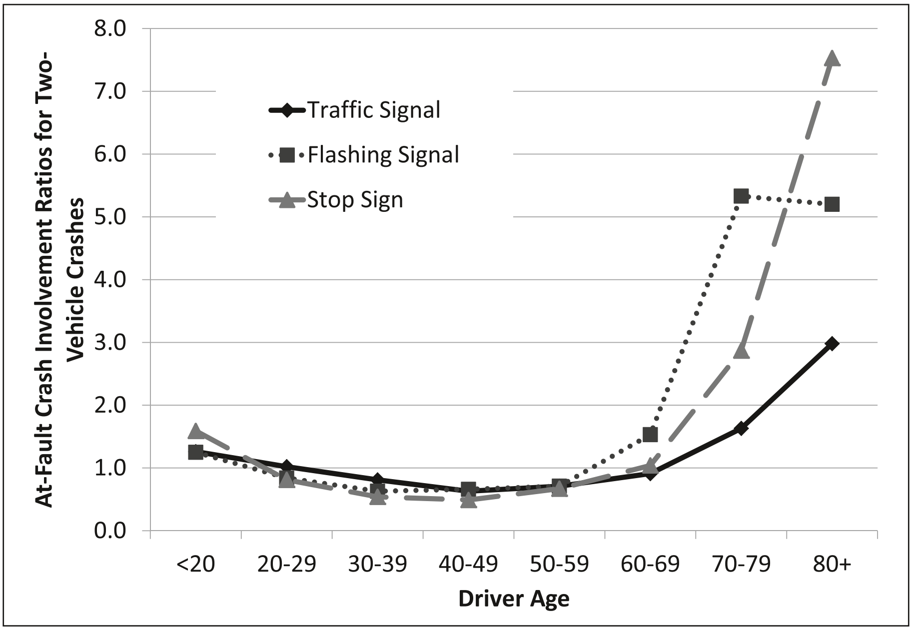

Figure 49: At-fault crash involvement ratios for two vehicle crashes at intersections with different controls, based on FARS data (Stutts et al., 2009).

Preusser et al. (1998) point out that for older drivers having a crash after running a stop sign is unlikely to be a deliberate violation but rather reflects difficulties in perception, decision making and action execution with older age.

Braitman et al. (2007) found that older drivers aged 70-79 made more evaluation errors, meaning that they saw the oncoming vehicle but misjudged its distance and speed (i.e. the TTC). However, for drivers older than 80 years, the likelihood of not seeing or detecting the other vehicle at all increases again. Although this error is also common with younger drivers, the reasons for making it are different between the age groups: whereas it is declining abilities in the case of the older drivers, it is distraction in the case of the younger drivers.

However, Li, Braver and Chen (2003) also point out that the reason for the high fatality rate of older drivers at intersections might particularly be due to their high frailty, especially in side impact collisions – which are typical for intersection crashes (see above). Nevertheless, as crashes per se also show a higher proportion of older drivers, it is likely a combination of both frailty and declining abilities which is responsible.

The reasons given above for intersection-crashes of the older drivers explain why traffic lights with protected left turns are an effective countermeasure: they reduce the situation`s complexity by simplifying decision making and they limit the chance of oncoming vehicles which can be overlooked.

8.3 Light conditions

Given the declining visual capability with age, it could be assumed that older drivers are greatly affected by darkness. However, this is not the case as can be seen when looking at the absolute accident figures (see Chapter 5.1): older drivers` accidents and fatalities are always lower during the night when compared to younger drivers (Ward, Shepherd, Robertson, & Thomas, 2005). Of course, as explained in Chapter 9.1, this is because older drivers avoid driving at night. (Whether this is because they consciously avoid driving at night because they are aware of their declining sensory abilities or because they simply do not have to be or want to be out late at night is secondary).

The data shown in Figure 50 is very interesting because it takes into account the actual exposure and thus gives a more realistic picture of the risk involved with driving in different light conditions. Interestingly, even taking into account exposure, driving at night is seemingly not riskier than driving during daylight. The authors of this study (Stutts et al., 2009) also explain this by compensation: older drivers only drive at night when they feel that it is as safe as driving during the daytime. What is interesting is the data for driving at dusk: this data shows a disproportionate increase in risk for older drivers. The reason for this increase could be that older drivers are less aware that their decreasing sensory abilities are already affected at dusk. Therefore, they might be less inclined to consciously avoid this situation or they might even be caught off-guard by dusk (as happens to all drivers from time to time).

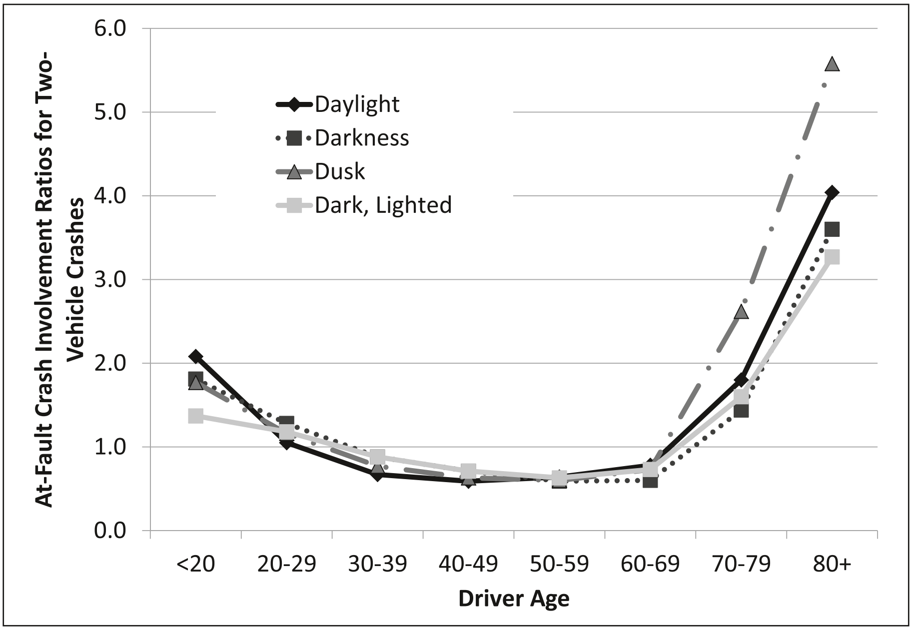

Figure 50: At-fault crash involvement ratios for two vehicle crashes and different age groups in different light conditions, based on FARS data (Stutts et al., 2009).

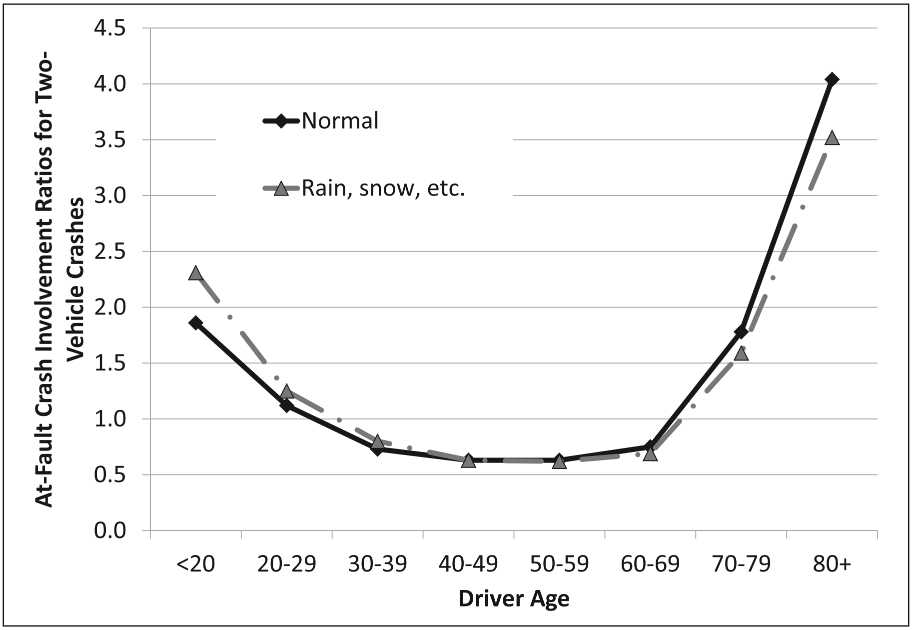

Figure 51: Two vehicle crash involvement ratios for police-reported crashes by weather conditions, based on FARS data (Stutts et al., 2009).

8.4 Weather conditions

Similar to the finding for light conditions, the results for weather conditions show some peculiarities: unlike one might expect, the percentage of accidents occuring during bad weather declines with age (Institute of Advanced Motorists (IAM), 2010). {Formatting Citation}{Formatting Citation}Again, this is probably the result of a compensation strategy at the strategic level of driving: driving in wet weather conditions can be avoided due to greater journey flexibility after retirement. However, the exposure corrected risks tell a similar story: again driving in bad weather conditions is not associated with a higher risk for older drivers when compared to normal weather conditions (see Figure 51). The reason for this is probably again compensation on the manoeuvre and control level of the driving task (see Figure 54) that is a more cautious driving style.

9 Prospects for maintaining the safety of older drivers

Demographic changes and the increasing mobility needs of older people require solutions to be found that help satisfy these mobility needs in a safe way. The focus in the next chapters is on auto-mobility because car driving has seen an especially marked increase over the last years.

Before going into detail in subsequent chapters, some general considerations will be made. Firstly, design for older drivers must address their specific needs. These needs reflect the age-related changes as shown in Figure 12. Further sources for improvements can be found when analysing older drivers` accidents and their causes as was done in previous chapters. Both accidents and their causes can be looked at in contrast to younger comparison groups but can also be looked at without such a comparison group. The idea in the latter case is that both younger and older drivers will benefit from an age-friendly design.

There are three ways of coping with age-related declines in terms of driving (see Figure 52):

- Training and compensation as suggested in the model of selective optimization with compensation suggested by Baltes & Baltes (1990).
- Designing the infrastructure, the vehicles and other means of transportation in an age-friendly way.
- Screening and assessment. This can serve as a basis for training and compensation and must ultimately be accompanied with alternatives to driving in situations where the outcome recommends giving up driving.

A publication by the UK-based Institute of Advanced Motorists (IAM, 2010) further subdivides these three ways of improving the safety of older drivers into five groups:

- "Information – Informing older drivers where, when and why skills honed over many years of driving may be beginning to fail will encourage them to develop new skills to make them less at risk
- Driving assessments – Encouraging older drivers to undertake regular assessments designed to identify where, when and why they may be more at risk – and to show them how risk can be managed and reduced
- Understanding and managing impairment – Showing older drivers through information and driving assessments, practical ways to

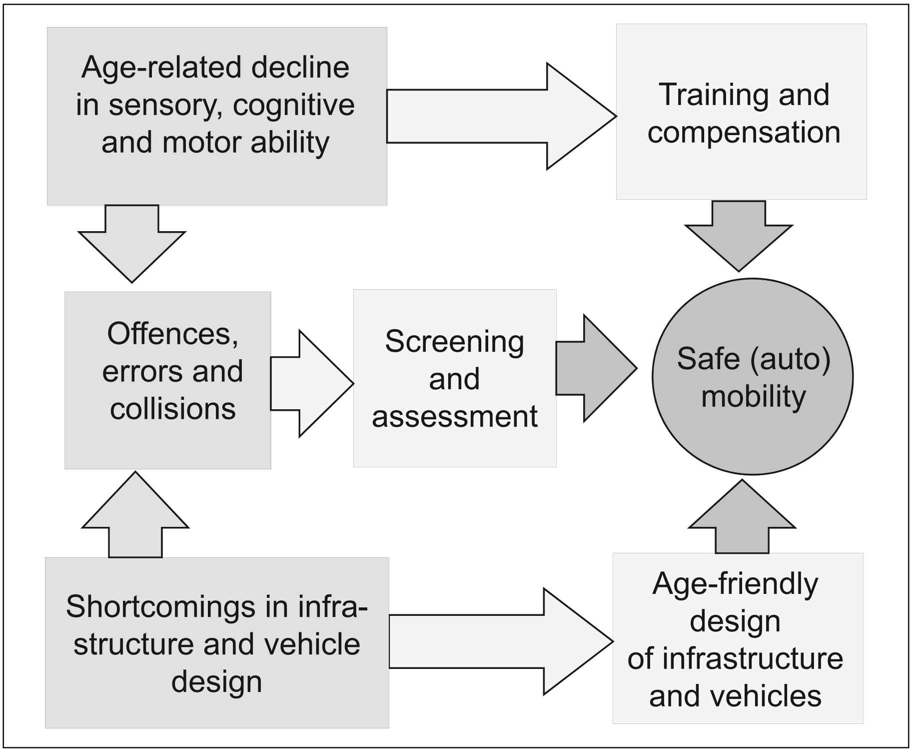

Figure 52: Three ways to ensure safe mobility in old age (source: SaMERU, 2013).

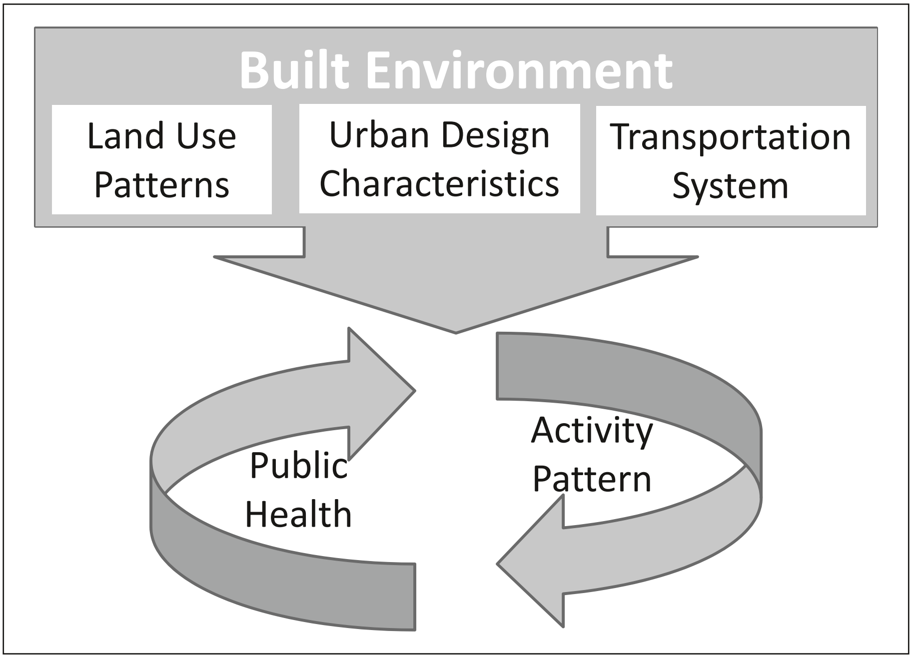

Figure 53: Model of the link between the built environment, activity patterns and public health (adapted from Frank, Engelke, & Schmid, 2003, p. 7).

overcome the age-related decline in skills, such as advanced route planning and tailored driving techniques
- Engineering safer roads – Designing and managing roads themselves to accommodate the needs of the growing population of older drivers; this would also benefit drivers of all ages
- Adapting vehicles – Designing vehicles to meet the needs of older drivers, and encouraging the fitting of extras that will assist safer driving, such as additional mirrors." (IAM, 2010, p. 3).

However, the built environment must be seen in its entirety. All aspects of built environment work are interrelated and together influence public health and mobility as proposed by Frank et al. (2003) (see Figure 53). The built environment is divided into land use patterns, urban design characteristics and the transportation system. When all are designed in an age-friendly way, the mobility of the elderly will be maintained until old age (Rosso, Auchincloss, & Michael, 2011).

Rosenbloom (2010) summed up measures from several studies that are useful in meeting older people`s mobility needs in the future. These also include non-driving related measures:
- "Training methods exist to substantially improve older drivers' skills in ways that allow them to drive safely longer,
- techniques, tools, and after-market equipment can be used to modify current vehicles in ways that make the driving task less demanding, reduce crash risks, and improve crash outcomes,
- the highway network, vehicles themselves, and the relationship between them, can be improved and enhanced through a variety of IT and related technologies to facilitate the driving task for older drivers and reduce crash rates,
- conventional public transportation services can be expanded and improved to better meet the travel needs of some older people, offering reasonable alternatives to older people before they are forced to cease driving,
- newer and different kinds of public transportation services more responsive to older people's travel patterns as they age can be implemented (following models used in Scandinavia and elsewhere),
- pedestrian facilities can be improved and enhanced using new design concepts and safer materials (e.g. to ameliorate fall outcomes), active enforcement (e.g. preventing cars or trash from blocking footpaths), and careful maintenance to encourage both recreational and purposeful walking as well as greater public transport use,

- accessibility mandates must be fully met and universal design concepts consciously applied in all building and infrastructure improvements,
- different kinds of urban design, city planning, and housing policies in both the public and private sector can offer meaningful alternatives to older people allowing them to live within walking or public transport distance of their homes, and
- existing community transport providers, paratransit services, and volunteer driver networks can and should be improved and substantially expanded to meet the needs of millions of older Yanks and Brits as they lose the ability to drive or use public transport or walk to meet their mobility needs." (Rosenbloom, 2010, p. 639).

In a diploma thesis at TU Dresden Schmidt (2004) conducted a survey among experts in older people´s mobility and safety both from the USA and from Germany. Different measures were proposed and were rated in terms of their importance and effectiveness for older people's mobility on a five point Likert scale ranging from 1 (very important/effective) to 5 (not at all important/effective). The results indicate that auto-mobility and measures to improve auto-mobility are not seen as particularly effective. The focus of the experts lies much more on alternatives to car driving and a holistic approach to older people's mobility (see Table 1).

Table 1: Rated effectiveness of different measures in improving older people`s mobility (1 to 5; 1 = very important/effective) (Schmidt, 2004)

Proposed Measure	**N**	**M**	**SD**
Promoting age-friendly living arrangements	48	1.73	1.05
Improving public transport	48	1.75	0.98
Developing alternative means of transportation	47	1.95	1.03
Improving road infrastructure	48	1.98	0.84
Assessing psychophysiological performance	47	2.17	1.01
Promoting driver trainings	48	2.25	1.04
Developing tailor-made services	47	2.28	0.68
Promoting mobility management	48	2.29	1.07
Promoting the support by relatives and friends	47	2.38	1.10
Improving vehicles and driver assistance systems	48	2.54	1.09
Installing information and navigation devices	48	2.79	0.99

Although such measures go beyond the scope of this report, others that deal with auto-mobility do and will be dealt with in more detail later. Before doing so, a measure applied consciously or unconsciously by the older drivers themselves will be focused on. This is the topic of compensation without which accident figures of older drivers would be much worse.

9.1 Compensation by the elderly themselves

Older drivers have a vast amount of driving experience. One could argue that this experience helps them to compensate for their declining abilities. However, this is not fully the case: especially in unknown situations and in situations that require an exact execution of the driving task, older drivers show deficiencies: Older drivers need more time to negotiate such situations (Cohen, 2001).

Taking more time is one example of compensation by older drivers, a more detailed list is given in Table 2 based on a publication by Simoes (2003). Such compensation often follows the model of selective optimization with compensation (SOC-model) developed by Baltes and Baltes (1990).

The terms in the SOC-model can be explained as follows:
- Selection: Only a selection of aims or destinations is pursued.
- Optimization: Existing abilities and measures are trained and optimized to reach the selected aims.
- Compensation: New, previously unused, measures are used. Examples might be mobility scooters or driver assistance systems.

Thus, the model claims that a positive development in older age is possible by efficiently using remaining resources.

In the context of driving, compensation along the lines of the SOC model can indeed be observed and may contribute to a reduction of traffic-related risks (Engeln & Schlag, 2008). Compensation can be performed at all levels of the driving task; some selected examples are shown in Figure 54.

However, with increasing age, compensation at the strategic level with a selection of aims or destinations seems the predominant way to compensate for declining abilities. This means that elderly drivers drive less

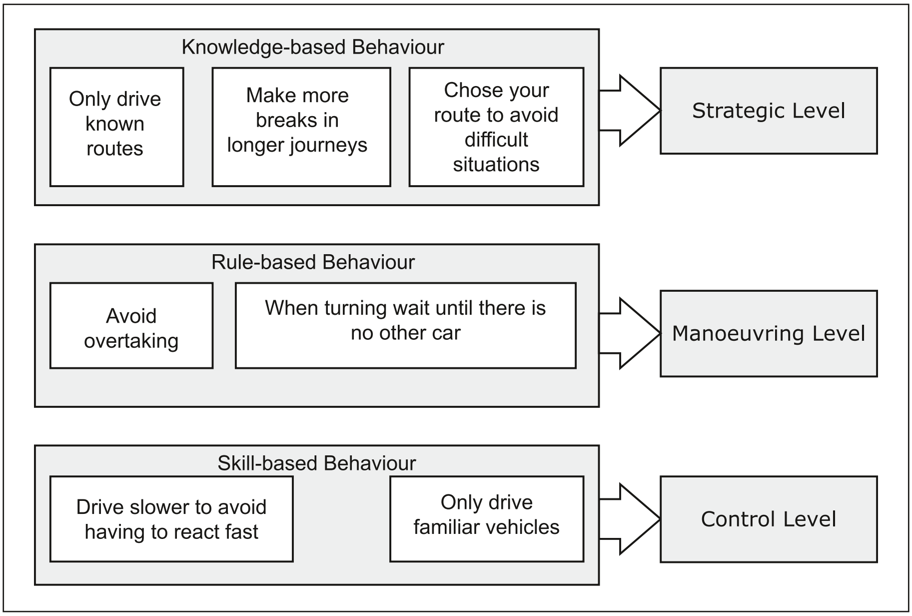

Figure 54: Selected compensatory behaviours at different levels of the driving task (for an explanation of the levels see Weller, 2010; Weller, Schlag, Gatti, Jorna, & van de Leur, 2006).

at peak hours, during the night or bad weather or even reduce travelling to far-away destinations by car (Breker et al., 2001). Hardly any negative consequences for the living quality of the elderly can be expected as long as these changes only result in activities being postponed to more convenient circumstances (better weather, off-peak hours).

Whereas it is assumed that older drivers compensate for their decreasing abilities, very little is known about the extent of this compensation: Do elderly drivers indeed use compensation and to what extent?

Ramulu, West, Munoz, Jampel, and Friedman (2009) found that drivers with glaucoma typically adapted their driving: they reported “cessation of night driving, less frequent driving, and cessation of driving in unfamiliar places” (p. 1848) more often than the group without glaucoma.

A study by Stalvey and Owsley (2000) where older drivers with visual impairments were asked whether they used different forms of compensation, showed that – depending on the kind of behaviour - between 30 and 60 % made use of compensation at least sometimes.

Baldock, Mathias, McLean, and Berndt (2006) used a questionnaire based on the one developed by Stalvey and Owsley (2000) (see Figure

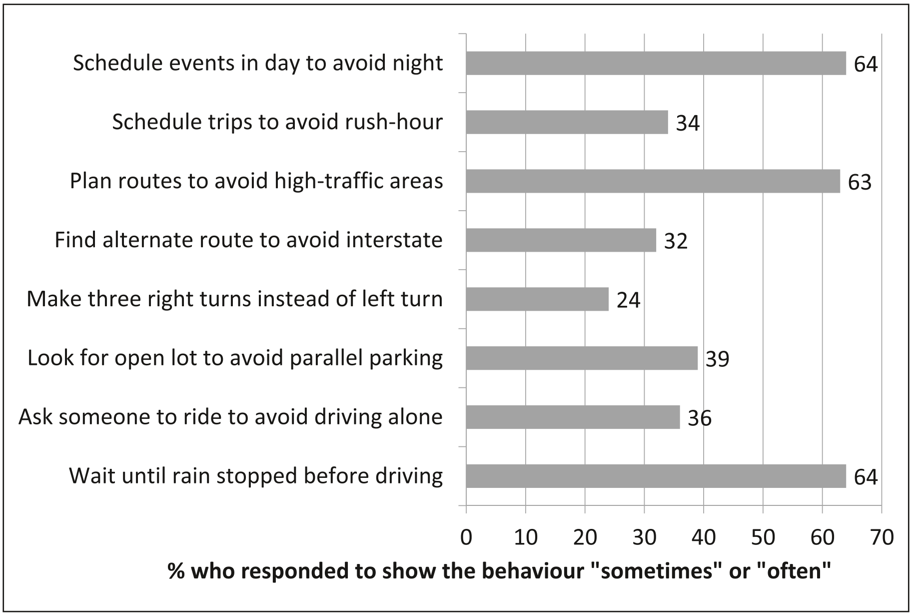

Figure 55: Performance of specific self-regulatory compensative strategies (based on Stalvey & Owsley, 2000).

55). Their survey (N=104 older Australian drivers) showed an overall lesser percentage of compensatory behaviour but nevertheless found that driving in rain and at night were amongst the most avoided situations.

In addition to the mere number of compensatory behaviours, the study by Baldock et al. (2006) also found that a small number of these behaviours (at night, in the rain, at night in the rain) also correlated with the results of driving tests: “Older drivers do appear to self-regulate in a manner consistent with driving ability but only for a small number of specific situations.” (p. 1042).

In a telephone survey of elderly Australians (N=322), Sargent-Cox et al. (2011) found that compensatory behaviour increased with age and the experience of at least one of a number of medical conditions such as bad eye condition or stroke. Of those being affected or having experienced such a medical condition around 75 % used some form of compensation. However, in the healthier subsample, a similar percentage still drove at night, longer distances and to unfamiliar locations.

Future generations of older drivers will bring more driving experience than previous cohorts and they will continue to bring their safer habits

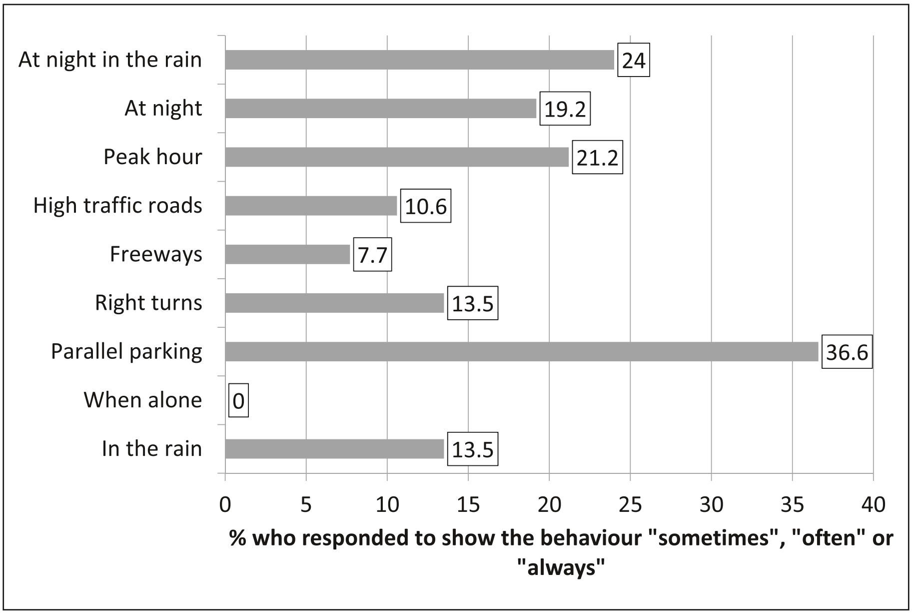

Figure 56: Performance of specific self-regulatory compensative strategies (based on Baldock et al., 2006).

with them into their retirement years (Rosenbloom & Ståhl, 2002). It is likely that this greater driving experience will lead to a stronger emphasis in optimization especially in familiar situations with more accurate and faster responses (Schlag, 1999).

Results indicate that older drivers restrict driving according to their self-perceived health and to problems experienced while driving (Rimmö & Hakamies-Blomqvist, 2002). It also seems that the sooner deficiencies in (visual) abilities occur, the more likely drivers are to restrict their driving (West et al., 2003). These findings indicate the importance of feedback on both health and driving behaviour to support older drivers in their decision to restrict (and ultimately to give up) driving.

Compensation on the strategic and sometimes on the manoeuvring level needs some form of conscious decision making. This requires that drivers be aware of their deficiencies and that they know which forms of compensation are available. At present there are a lot of sources on the internet that give advice to older drivers with certain medical conditions. One site is http://seniordriving.aaa.com/tools-additional-resources.

Training is necessary where optimization is involved. More details on training are given in the next chapter.

Table 2: Age-related declines in abilities, the corresponding difficulties in performing the driving task and compensatory behaviour (Simoes, 2003)

Part A: Declines in vision			
Age-related declines	**Declines in abilities related to driving**	**Difficulties in driving**	**Compensatory behaviours**
Sensitivity to light	Higher visual sensitivity threshold	Detecting dim lights in a dark environment, High sensitivity to glare	Avoid night driving
Dark adaptation	Slower rate for dark adaptation	Increasing glare recovery time	Avoid night driving
Visual acuity	Static visual acuity	Reading a road sign at a distance	Slower driving
	Dynamic visual acuity	Estimating speeds and distances of moving objects	Avoiding complex traffic conditions
Spatial contrast sensitivity	Contrast sensitivity for high frequency gratings	Seeing unexpected vehicles in the peripheral visual field	Avoid night driving
		Reading dim dashboard display panels, Seeing through windshields, Reading signs at a distance	Slower driving, Avoid complex traffic conditions

Part B: Declines in visual perception			
Age-related declines	**Declines in abilities related to driving**	**Difficulties in driving**	**Compensatory behaviours**
Eye movements	Saccadic movements	Longer time to locate objects	Compensation with head movements
	Pursuit movements	Perceiving details of moving objects	
	Restriction in the maximum extent of gaze without head movement		
Spatial perception	Perception of relative distances	Perceiving distances between driver`s car and the car ahead or the size of the gap for merging with or crossing a traffic stream	Avoid complex traffic conditions (non conclusive studies on direct effects in safe driving)
Motion perception	Sensitivity to angular displacement	Perceiving depth motion, Detecting the relative speeds of objects	Avoid complex traffic conditions, merging traffic, lane changes, overtaking

Table 2 (continuation): Age-related declines in abilities, the corresponding difficulties in performing the driving task and compensatory behaviour (Simoes, 2003)

Part B: Declines in visual perception (continuation)			
Age-related declines	**Declines in abilities related to driving**	**Difficulties in driving**	**Compensatory behaviours**
Colour perception	Colour vision associated with other age-related visual decrements	Discriminating traffic signs and lights	(non conclusive results on direct effects of poor colour perception in safe driving)
Visual field	Useful field of vision (UFOV)	Reduced UFOV, particularly when performing a secondary task or having distracting stimuli	Avoid distracting factors while driving (using telephone, passenger talking, using radio, etc.)

Part C: Declines in cognitive abilities			
Age-related declines	**Declines in abilities related to driving**	**Difficulties in driving**	**Compensatory behaviours**
Attention	Divided attention	Performing simultaneous tasks	Avoid simultaneous tasks (using telephone, passenger talking, using radio, etc.)
	Selective attention and attention switching	Filtering of useful information due to difficulties in inhibiting irrelevant information	Concentrate on the driving task, sometimes neglecting any displayed information
Memory	Working memory (WM)	Longer time to access information in WM, hesitancy in decision making, both increasing with traffic complexity	Slow driving, hesitant driving and unexpected manoeuvres
	Long-term memory (LTM)	Formation of new long-term memories, recalling driving laws, remembering what to do in specific driving situations, particularly in modern road environments and vehicles	Avoiding driving in complex traffic conditions, rush hours and unknown environments, due to increasing difficulty in driving nowadays
Problem solving	Decision making	Deciding to travel through an intersection with an amber light, figuring out how to navigate across town, determining the appropriate driving speed, etc.	Avoid complex traffic conditions, rush hours and unknown environments

Table 2 (continuation)

Part C: Declines in cognitive abilities (continuation)			
Age-related declines	**Declines in abilities related to driving**	**Difficulties in driving**	**Compensatory behaviours**
Spatial cognition	Mental rotation	Slower and less accurate mental rotation of images	Avoid the use of maps, just drive in well-known environments
	Cognitive mapping	Spatial representations, remembering and recalling landmarks, creating detailed and organized maps of their neighbourhoods, even when well known	
	Way finding	Navigating and finding locations	
Perceptual style	Increased field dependence	Fixations concentrated within a narrow field of view, leading to difficulties in target detection in complex environments, increased time for searching the road for driving-related information	Avoid congested traffic, motorways and unknown environments, due to reduced ability to control skidding vehicles, to use information about accelerating and braking of other vehicles and to drive defensively in high speed traffic

Part D: Declines in psychomotor skills			
Age-related declines	**Declines in abilities related to driving**	**Difficulties in driving**	**Compensatory behaviours**
Reaction time	Increased choice reaction time	Slower information processing	Slower driving
Motor coordination	Less accuracy in movement	Decrease in precision of both discrete and continuous movements	No significant influence on driving performance, except for novice older drivers

Part E: Declines in motor skills			
Age-related declines	**Declines in abilities related to driving**	**Difficulties in driving**	**Compensatory behaviours**
Range of motion and reaching distances, Loss of muscle strength, endurance and tone	Reduced range of neck motion	Scanning road environment and performing reversing manoeuvres	Avoid parking manoeuvres, lane changes, merging traffic, overtaking and other high risk driving situations

9.2 Training of driving ability for older drivers

The idea behind driver training is the same as for any other training: “use it or lose it”.

As is depicted in Figure 53, training is one of the three groups of measures which help to ensure safe mobility. In general, there are two time slots when to provide training for older drivers: independent of an assessment or following an assessment. This results in two kinds of training:

Training can be generic which means that it is made available to older drivers, regardless of their individual needs and background. Such training would be based on the general knowledge of age-related changes as depicted in Figure 12. The common element of the different forms is that they follow a predefined agenda. Three different kinds of training can be distinguished within such generic training measures: theoretical training, practical training and a combination of both.

Theoretical training can be understood as the provision of information which is also available in guidelines for safe driving in old age (such as those found on www.olderpersonsroadsafety.com/). Such training also helps older drivers to get a realistic impression of their abilities

Figure 57: Driving training with elderly drivers in Lancashire (source: SaMERU, 2013).

and thus helps to establish a more realistic self-image (see Chapter 6). They should teach older drivers to self-assess their driving ability and how to compensate (see Chapter 9.1). The presence of a trainer and the group-setting help learning and additionally support the exchange of experiences amongst the peer group.

Practical training is often conducted on a closed test track and usually includes some kind of driving dynamic training. An example of such training was conducted in the SaMERU project in Modena and is described in the relevant SaMERU report. A list of such generic driver training and education programs can be found in Ford (2009). Usually, theoretical and practical training are combined.

Besides generic theoretical or practical training, training can also be tailor-made to meet individual needs and requirements. This training would probably be conducted after an assessment of the specific needs of an individual driver but not necessarily following an incident in traffic. The assessment can be conducted in a laboratory with the help of different tests or on the road as an assessment of the individual's driving quality. The training following such assessment requires that a single driver and not a group of drivers is trained. This kind of training is usually conducted in real traffic by a driving instructor and consists of several training sessions on different days (see Figure 57).

The positive effects of such training are described in Poschadel, Boenke, Blöbaum, and Rabczinski (2012) (see Figure 58). In this study, three groups of drivers took part: a younger comparison group (N=28) aged 40 to 50 years, an experimental group which received the driving training (N=46), aged 67+, and a feedback group (N=46) with similar age characteristics.

Driving competence (the ordinate in Figure 58) was measured once for the comparison group and four times for the two other groups (see TRIP 1 to TRIP 4 on the abscissa of Figure 58). It was assessed by averaging the ratings of a driving instructor and an experimental leader, on 96 items of an adapted form of the TRIP protocol (TRIP = Test Ride for Investigating Practical fitness-to-drive, see De Raedt & Ponjaert-Kristoffersen, 2001). The ratings on each item ranged from "one" = "good" and meaning that the criteria were met in 76-100 % of cases, to "four" = "insufficient" with criteria being met in zero to 25 % of cases.

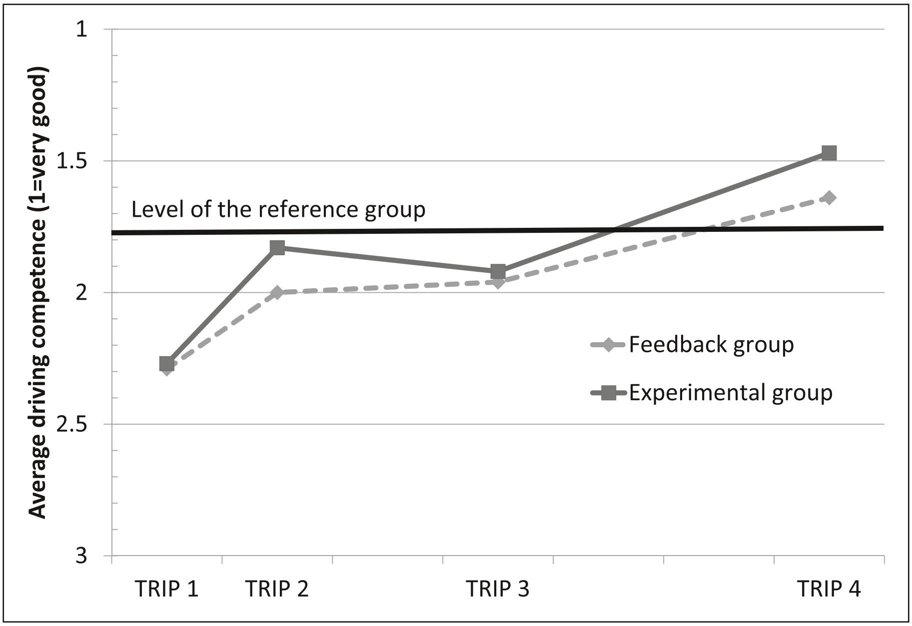

Figure 58: Effect of training on driving competence (Poschadel et al., 2012).

The training was highly individualized and adapted to the needs of the individual driver with the aim of training lane-changes, turning left and negotiating complex intersections. Each driver in the experimental group received 15 driving lessons on different days between TRIP 1 and TRIP 2 (see abscissa in Figure 58). The feedback group only completed the test course and was given feedback after each TRIP. It did not receive any other training. The assessment of the driving quality (TRIP 1 to TRIP 4) was conducted before the training (TRIP 1), after the training (approximately six weeks after TRIP 1), six months after TRIP 1 (=TRIP 3) and one year after TRIP 1 (=TRIP 4).

There are some remarkable findings of the study by Poschadel et al. (2012):

- Driver training is a successful means to improve the driving quality (and safety) of older drivers.
- On average, simple feedback on driving errors and driving quality helps to improve driving quality.
- Although simple feedback is successful on average, even better results can be obtained by tailor-made driving lessons.
- When only the worst drivers within each group are looked at, it is only the tailor-made driving lessons that resulted in a massive improvement.

However, the positive effect of feedback on driver behaviour was also shown in a study by Romoser and Fisher (2009). In this study, a simulator was used and feedback was given to improve the scanning behaviour at intersections. The importance of feedback in training for older people (independent of the context) is also described in Nichols, Rogers, and Fisk (2006).

Researchers from the Psychological Institute of the University Zurich are currently analysing whether training in a driving simulator also has positive effects on driving performance of older drivers.

In this project ("Drive Wise") a driving test was conducted pre and post either simulator training or merely cognitive training. Although the data are not yet fully analysed and the results are not yet published, preliminary results indicate that simulator training does improve on-road driving performance of elderly drivers (Jäncke & Casutt, 2012). The cognitive training resulted in an increase in the cognitive tests but had less effect on actual driving performance.

However, even the improvement in the cognitive tests – which also included a test of peripheral vision and motor reaction tasks – might be relevant for driving. This is the case in relation to reacting to sudden events or the perception of relevant information in the visual periphery. Earlier results of this work group also suggest that tracking performance can be trained (Lutz, Martin, & Jäncke, 2010).

Other studies showed that cognitive (Ball et al., 2007; Ball et al., 2010) and motor (Rinkenauer, 2008; Voelcker-Rehage & Willimczik, 2006) function can be trained and improved even in old age. Edwards, Delahunt, and Mahncke (2009) found that cognitive training (speed of processing) reduced the percentage of drivers that quit driving over a three year period from 14 to 9 %. Given the supposed relationship between sensory, cognitive and motor function and driving performance – which implicitly underlies all psychological tests in relation to licensing of older drivers – such findings are highly relevant. Further information on training of cognitive and motor abilities in old age can also be found in the SaMERU report on WP1.11. In a recent study, Hunt, Harper, and Lie (2011) found that gap perception can be trained both with younger and older participants. The training leads to more accurate and conservative gap decisions. Regarding the long term effects of training, the results are all promising, especially given the speed with which performance can change in older age. In addition to the study by Poschadel et al. (2012, see above), Romoser (2013) showed that the training in Romoser's and Fisher's study (2009, see above) had lasting positive effects even two years after the training.

With so many positive aspects of training it is not surprising that the level of acceptance is high. In a survey published by Robertson and Vanlaar (2008), training was found to be the most accepted means to ensuring the safety of older drivers. The rate of agreement with compulsory training was around 75 % compared to restricted privileges (70 %) and losing the licence after a crash (40 %). However, it must be noted that only 20 % of people of the survey sample were aged 60+. Given the differences in self-assessment between younger and elder drivers (Richter et al., 2010), the acceptance rate might decline when only older drivers are asked for their opinion.

To sum up the effectiveness of training for older drivers, it can be stated that:

- It increases consciousness and knowledge regarding general and individual driving related limitations (Eby, Molnar, Shope, Vivoda, & Fordyce, 2003; Marottoli et al., 2007; Owsley, Stalvey, & Phillips, 2003).
- It improves driving performance.
- It improves safety, although the relationship between training and accidents is difficult to prove (G. E. Nasvadi & Vavrik, 2007; Owsley et al., 2003).
- It is cost-effective and has a high level of acceptance in society.

9.3 Road design measures

9.3.1 General considerations

Road design measures are engineering measures that reflect older drivers' needs. Such measures can take several forms and their implementation depends on the characteristics of the location and the financial resources available.

Before discussing some measures in detail, some general advice is given regarding the prioritisation of solutions. In the field of human factors, solutions to safeguard against accidents follow a hazard control hierarchy. According to this hierarchy, the effectiveness of solutions decreases as follows (Wogalter, 2006):

- Design the hazard out,
- Guard against the hazard,
- Warn the users of the hazard.

Applied to road traffic, this means that passive safety measures and signage are supposed to be less effective than a road design that removes the hazard or makes the driver behave in a way that the hazard no longer is dangerous, for example by decreasing speed.

One way of removing hazards is by designing self-explaining roads. This term was originally created and defined in the Netherlands by Theeuwes and Godthelp (1995):

"Traffic systems having self-explaining properties are designed in such a way that they are in line with the expectations of the road users. The [...] "Self-Explaining Road" (SER) is a traffic environment which elicits safe behaviour simply by its design."(p. 217).

The principles behind self-explaining road design were summarized by the authors and published by Theeuwes (2000, p. 21) as follows:

- "Roads should consist of unique road elements (homogeneous within one category and different from all other categories).
- Roads should require unique behaviour for a specific category (homogeneous within one category and different from all other categories).
- Unique behaviour displayed on roads should be linked to unique road elements (e.g., woonerfs: obstacles - slow driving, freeway: smooth concrete - fast driving).
- The layout of crossings, road sections, and curves should be linked uniquely with the particular road category (e.g., a crossing on a highway should physically and behaviourally be completely different from a crossing on a rural road).
- One should choose road categories that are behaviourally relevant.
- There should be no fast transitions going from one road category to the next.
- When there is a transition in road category, the change should be marked clearly (e.g., with rumble strips).
- When teaching the different road categories, one should not only teach the name of, but also the behaviour required for that type of road.

- Category defining properties should be visible at night as well as in the daytime.
- The road design should reduce speed differences and differences in direction of movement.
- Road elements, marking, and signing should fulfill the standard visibility criteria."

Further information on SER, especially regarding its history, can be found in Charman et al. (2010) and examples of its application can be found in Theeuwes (2012). While the principles above are applicable on a larger scale – especially regarding road categorization - some of them are also applicable on a smaller, local scale. In fact, some can similarly be found in the "Highway Design Handbook for Older Drivers and Pedestrians" by Staplin, Lococo, Byington, and Harkey (2001).

Regarding older drivers, the SER philosophy can be interpreted as "reducing ambiguity". Reducing ambiguity is especially important for older drivers because of their declining resources. Ambiguity requires that resources are invested to either resolve the ambiguity for oneself or deal with the ambiguous and unpredictable behaviour of other traffic participants. The relationship between overload – that is a situation in which demand exceeds capacity or resources – and accidents was modelled by Fuller (2005) (see Figure 59). As can be seen in Figure 59, both task demand and capability vary with time and distance driven. Task demand varies depending on the situation, both the static situation and the dynamic situation. The static situation is represented by continuing elements such as road geometry and pavement characteristics, the dynamic situation is represented by varying elements such as other road users and weather characteristics. Capability also varies with time and distance driven. It is influenced by factors such as time-on-task (i.e. getting tired), circadian rhythm or medication. According to the model, danger arises when task demand exceeds capability.

Thus, the aim of SER design is to ensure that neither overload nor underload occur and that the driver automatically exhibits the appropriate behaviour without any external enforcement needed.

Of course, the concept of SER at this stage is rather a design philosophy and not yet an engineering manual for road layout. However, the concept as such should be considered for every location and every design

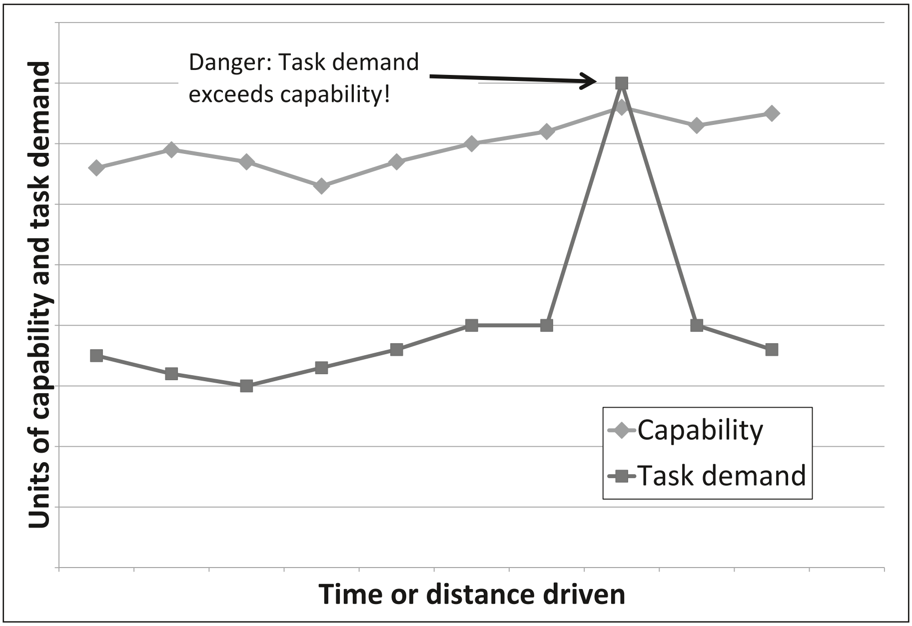

Figure 59: Schematic task-capability interface model by Fuller (2005).

should be evaluated against it. The idea is that SER is especially helpful for older drivers because it reduces ambiguity and thus increases safety.

The starting point for developing age-friendly solutions must again be the declining resources of older drivers. Davidse (2007) has juxtaposed them to road-based solutions for older drivers (see Table 3).

Table 3: Functional limitations of older adults and relevant road design elements (Davidse, 2007)

Functional limitations	**Relevant factor**	**Relevant road design elements**
Peripheral vision and flexibility of head and neck	Quality of the information	Angle at which streets meet
Night-time visual acuity and sensitivity to glare	Quality of the information	Fixed lighting, Design of traffic signals
Contrast sensitivity and motion perception	Quality of the information	Assistance for turning left, Contrast of pavement markings, Design of traffic signs and signals, Design of street-name signs

Table 3 (continuation): Functional limitations of older adults and relevant road design elements (Davidse, 2007)

Functional limitations	Relevant factor	Relevant road design elements
Colour vision	Quality of the in- formation	Design of traffic signs and signals
Divided attention	Number of decisions	Type of intersection (roundabout)
Selective attention	Amount of information	Placement of traffic signs
Speed of information pro- cessing, divided attention, and performance under pressure of time	Time pressure	Angle at which streets meet, Lane-use control signs, Type of intersection (roundabout), Placement of traffic signs , Fixed lighting

This list is an important contribution as it helps to understand the background behind solutions designed for older drivers. The frequency of solutions aimed at improving visual perception (markings, lighting, signs) is notable and reflects the importance of vision driving. However, solutions based on the SER-concept are more subtle and include the entire roadway and its environment to convey the message regarding appropriate behaviour.

Perhaps the most cited, most extensive and yet precise guidelines on how to design age-friendly roads is the “Highway Design Handbook for Older Drivers and Pedestrians” by Staplin et al. (2001). In this guidebook, specific measures were collected based on existing guidebooks and were developed further to reflect the needs of older drivers. These measures were applied to five different road design elements:
- Intersections (at-grade)
- Interchanges (grade separation)
- Roadway curvature and passing zones
- Construction/work zones
- Highway-rail grade crossings (passive)

Each of these five higher-order elements was subdivided into lower-order road design elements that are usually part of these higher-order elements. Specific guidelines are then provided for each subcategory. Before focusing on selected recommendations, an overview is given regarding the subdivision of the five elements:

- Intersections (at-grade):
  1. Intersecting angle (skew)
  2. Receiving lane (throat) width for turning operations
  3. Channelization
  4. Intersection sight-distance requirements
  5. Offset (single) left-turn lane geometry, signing, and delineation
  6. Edge treatments/delineation of curbs, medians, and obstacles
  7. Curb radius
  8. Traffic control for left-turn movements at signalized intersections
  9. Traffic control for right-turn/right-turn-on-red (RTOR) movements at signalized intersections
  10. Street-name signing
  11. One-way/wrong-way signing
  12. Stop- and yield-controlled intersection signing
  13. Devices for lane assignment on intersection approach
  14. Traffic signals
  15. Fixed lighting installations
  16. Pedestrian crossing design, operations, and control
  17. Roundabouts

- Interchanges (grade separation)
  1. Exit signing and exit ramp gore delineation
  2. Acceleration/deceleration lane design features
  3. Fixed lighting installations
  4. Traffic control devices for restricted or prohibited movements on freeways, expressways, and ramps

- Roadway curvature and passing zones
  1. Pavement markings and delineation on horizontal curves
  2. Pavement width on horizontal curves
  3. Crest vertical curve length and advance signing for sight-restricted locations
  4. Passing zone length, passing sight distance, and passing/overtaking lanes on two-lane highways

- Construction/work zones
  1. Lane closure/lane transition practices
  2. Portable changeable (variable) message signing practices
  3. Channelization practices (path guidance)
  4. Delineation of crossovers/alternate travel paths
  5. Temporary pavement markings

- Highway-rail grade crossings (passive)
    1. Passive crossing control devices

Because the specific measures named in the guidebook (Staplin et al., 2001) often relate to specific design elements in the USA, they cannot all be named and discussed in detail in this report. Furthermore, specific values are subject to change with changing demand and new design elements. Therefore, for the context of this report, it is more appropriate to provide some general advice and leave the specific values to the national authorities.

Focusing on the elements and not on their specific, situation-dependent value allows grouping those measures that are applicable to different elements. Such a summary is provided in a report by Potts et al. (2004):

1. Provide advance warning signs.
2. Provide advance guide signs and street name signs.
3. Increase size and letter height of roadway signs.
4. Provide all-red clearance intervals at signalized intersections.
5. Provide more protected left-turn signal phases at high-volume intersections.
6. Provide offset left-turn lanes at intersections.
7. Improve lighting at intersections, horizontal curves, and railroad grade crossings.
8. Improve roadway delineation.
9. Replace painted channelization with raised channelization.
10. Reduce intersection skew angle.
11. Improve traffic control at work zones.

Similar recommendations are given by Boltze (2013).

When having to decide which measure to implement first, practitioners might find it helpful to know what other experts say regarding the general effectiveness of a given measure. Such expert-ratings were collected from North America and Europe by Schmidt (2004) (see also Schlag & Engeln, 2005). The results are shown in Table 4.

The majority of measures rated as effective is based on safer intersection design, particularly for turning left. An additional group of measures is related to signage, lighting and markings. These could be summarized as improving the visual perceptibility of a situation.

However, regarding traffic signs, one also has to note that the experts were rather critical regarding redundant signage and simply enlarging signs. The reason is that such measures contradict the measure rated the most effective: “Simplify traffic information”. Furthermore, signs in general are not self-explaining in the sense of the self-explaining road concept. Their meaning must be learned and they are usually only used when the road design is not self-explaining. Furthermore, they might not be perceived. Thus, even the measures named in the guidebook (Staplin et al., 2001) must be discussed in a critical way.

Table 4: Ratings of the effectiveness of road-related measures to improve the safety of older road users (N=48; 1=very effective to 5=not at all effective) (Schmidt, 2004)

No.:	“How effective is the measure to increase the safety of older drivers?”	M	DE/AT/CH	US/CA
1	Simplifying traffic information	1.70	1.73	1.60
2	Implementing protected left-turns at traffic lights	1.75	1.96	1.48
3	Implementing traffic lights	1.81	1.88	1.70
4	Standardising traffic organisation and signage especially at dangerous locations	1.91	2.04	1.70
5	Setting off the lane for turning left at intersections	1.95	2.18	1.61
6	Increasing the minimum reaction time for road planning to 2.5 s	2.09	2.38	1.78
7	Installing street lighting at dangerous locations and motorway entrance ramps	2.15	2.23	2.00
8	Simplifying intersection designs	2.16	2.32	2.00
9	Installing particularly large and light intensive signal lamps	2.17	2.44	1.86
10	Treating median and island curb sides and curb horizontal surfaces with retroreflective markings	2.18	2.46	1.80
11	Implementing self-explaining roads	2.20	2.09	2.25
12	Reducing speed at intersections and urban roads (except for through roads)	2.21	2.24	2.24
13	Implementing particularly large and conspicuous traffic signs	2.24	2.54	1.80
14	Designing intersections with angles between 75° and 90°	2.30	2.40	2.12

Table 4 (continuation): Ratings of the effectiveness of road-related measures to improve the safety of older road users (N=48; 1=very effective to 5=not at all effective) (Schmidt, 2004).

No.:	"How effective is the measure to increase the safety of older drivers?"	M	DE/AT/CH	US/CA
15	Providing guidance by using raised channelization with sloping curbed medians	2.35	2.75	1.81
16	Installing warning signs or lights for turning right WHEN RED	2.47	2.67	2.20
17	Installing roundabouts	2.48	2.08	3.06
18	Installing redundant signage	2.63	3.13	2.05
19	No turning right WHEN RED at intersections with angles less than 75°	2.74	3.05	2.35
20	Implementing a minimum receiving lane width of 3.6m	2.98	3.12	2.79
Note: DE = Germany, AT = Austria; CH = Switzerland; US = USA, CA = Canada				

9.3.2 Intersection design

In the following paragraphs, some of these measures will be introduced and discussed in more detail. Because of their importance for older drivers, the measures selected are mostly related to intersections. Even more specifically they are related to left-turn manoeuvres, again due to their high relevance for older drivers' safety. These situations are particularly difficult and dangerous for older drivers because of their reduced sensory, cognitive and motor abilities (see Chapter 3). These declining abilities lead to problems in estimating speed and distance of other vehicles and result in problems when selecting appropriate gaps.

Perhaps the most effective safety measure at intersections is protected left-turns. This measure was also rated with the (second) highest effectiveness by European and North-American experts (see Table 4). It requires that traffic lights are installed and that an additional lane for turning left is available. In the guidebook, the respective recommendations for this situation are given as:

1. "The use of protected-only operations is recommended, except when, based on engineering judgment, an unacceptable reduction in capacity will result.

2. To reduce confusion during an intersection approach, the use of a separate signal face to control turning phase (versus through) movements is recommended for all operating modes

3. Consistent use of the R10-12 sign, LEFT TURN YIELD ON GREEN, during protected-permitted operations is recommended, with overhead placement preferred at the intersection.

4. Where practical, the use of a redundant upstream R10-12 sign (i.e., in addition to the R10-12 sign adjacent to the signal face) is recommended to advise left-turning drivers of permitted signal operation. It is also recommended that the sign be displayed at a 3-s preview distance before the intersection, or at the beginning of the left-turn lane, as per engineering judgment, accompanied by a supplemental plaque bearing the message, AT SIGNAL. […]

5. A leading protected left-turn phase is recommended wherever protected left-turn signal operation is implemented (as opposed to a lagging protected left-turn phase).

6. To eliminate confusion about the meaning of the red arrow indication, it is recommended that the steady green arrow for protected-only left-turn operations terminate to a yellow arrow, then a steady circular red indication (instead of a red arrow).

7. Where minimum sight-distance requirements as per recommendations for Design Element D are not practical to achieve through geometric redesign/reconstruction, or where a pattern of permitted left-turn crashes occurs, it is recommended that permitted left turns be eliminated and protected-only left-turn operations be implemented." (Staplin et al., 2001, p. 22).

It becomes evident when regarding proposal (1) that an age-friendly design is sometimes in conflict with other interests in traffic such as traffic flow and capacity. It is worth noting that Potts et al. (2004) explicitly state that protected left-turns should be implemented at high-volume intersections (see above, Recommendation 5 by Potts et al. (2004).

Figure 60 shows an example of a protected left turn regulation. This kind of traffic regulation is particularly age-friendly because it reduces ambiguity (see above) and because it eliminates the hazard (i.e. it "designs the hazard out", see above, Wogalter, 2006). This allows older drivers to concentrate on their path without having to check for oncoming traffic. Furthermore, it relieves the driver of having to select a gap in oncoming traffic, a task at which older drivers are particularly bad (see above). All in all, protected left-turns considerably reduce workload and the demand on resources with respect to perception, decision making and reaction.

Figure 60: Example of a protected left-turn regulation with separate green phases for turning left versus going straight (source: SaMERU, 2013).

Figure 61: US-Sign R10-12 which is recommended by Staplin et al. (2001) but viewed critically by the authors of this report (original sign-picture taken from trafficsigns.us copyright Richard C. Moer).

Given these advantages of a protected left-turn, it is astonishing why Staplin et al. (2001) propagate the use of the “Left turn yield on green” sign (see Figure 61). The problem is not the sign per se but the traffic regulation it is made for: despite having green, drivers turning left have to yield to oncoming traffic. Such regulations and such signs are against SER-principles.

Of course, using the sign for the traffic regulation it is made for is better than not using it. However, the better way would be to install a proper protected left-turn lane with separate green phase traffic lights. Only the latter has a positive impact on older driver safety.

As has been pointed out before, ambiguity should be reduced to reduce older drivers' workload. Unfortunately, there are still numerous examples where this principle is not followed. One such example is the permanent, solid green arrow used mainly in eastern Germany. This arrow allows

Figure 62: The German sign permitting right turn on red (solid green arrow) might lead to uncertainty and danger for older drivers (example of situation in Dresden) (picture: Weller).

turning right even when the traffic light is red. However, this has no effect on the drivers coming from the left which means that the driver has to select an appropriate gap, a task in which older drivers are very bad. Although the sign has a positive effect on traffic flow it might be detrimental to older drivers. This is especially the case because they might feel pressured by other drivers.

Figure 63: Traffic light with head-start for cyclists. Although this can cause ambiguity for drivers not familiar with this regulation it will probably not be dangerous as other traffic participants have a red light (example of situation in Dresden) (picture: Weller).

Another example of an ambiguous regulation is shown in Figure 63. The picture shows a traffic light with head-start for cyclists. Although this might cause ambiguity for drivers not familiar with the regulation this regulation is recommended. This is because the ambiguity cannot cause dangerous situations for the drivers because the crossing traffic has a red light. At the same time it dramatically increases cyclists' safety.

The guidebook further recommends two engineering measures: positive offsets at intersections (see Figure 64) and ideal intersection angles of 90°.

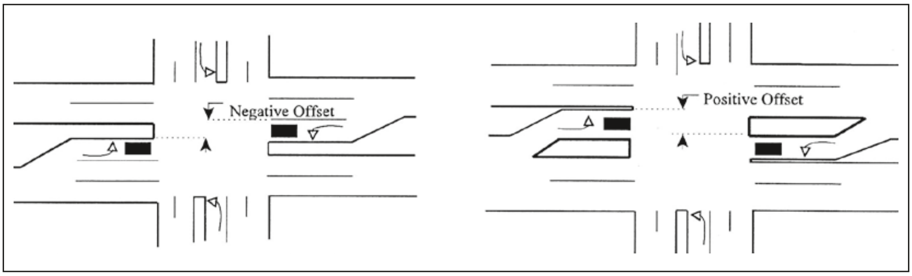

Figure 64: Left turn lanes with negative and positive offset, the latter providing better sight distances (source: Staplin et al., 2001).

The positive offset has the advantage of providing better sight and of reducing potential conflicts between turning vehicles from opposing directions. Thus it is especially useful at intersections without protected left turns.

Figure 65 shows an example of a skewed intersection angle. It is recommended to reduce intersection skew (Davidse, 2007; Potts et al., 2004; Schmidt, 2004). However, as can be seen in the example, redesigning existing intersections and changing their angle will be extremely costly. Therefore, this measure is more applicable to new intersections. Mirrors can be installed at existing intersections to improve sight into the incoming priority-lane.

However, it is not only skew that reduces sight at intersections. Even at intersections with streets crossing at 90° sight can be obstructed by road furniture, plants or parked cars. Because of their longer processing and reaction times it is very important for older drivers to improve sight distances at intersections. However, this applies to all road situations that require reactions to be made quickly. An example of such a situation is shown in Figure 66. These two pictures taken from Boenke, Gerlach, Rönsch-Hasselhorn, and Conrad (2010) show a pedestrian crossing

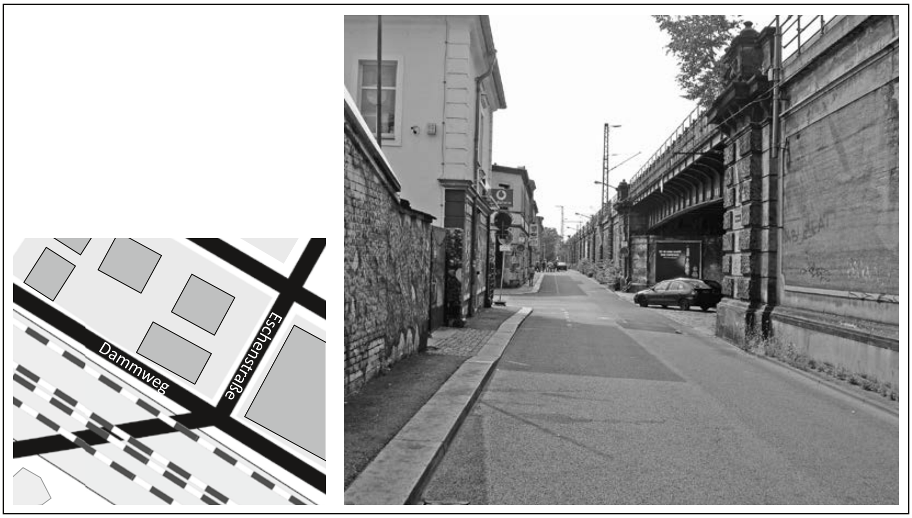

Figure 65: Skewed intersection angles are particularly demanding for older drivers because of decreased neck mobility. The picture shows a negative example from Dresden, Germany (picture: Weller).

Figure 66: Legal regulations regarding sight distances must be enforced to ensure that older drivers can cope (source: Boenke et al., 2010/GDV).

with and without a parked car in front of this crossing. The difference the parked car makes with regard to sight distance reaction time becomes evident.

In most countries, legal regulations exist that aim to ensure that such requirements of sight distances are met. However, especially in inner city traffic, the problem is that such regulations must be enforced. Self-enforcing design is a better option than control by the police or other enforcing agencies. In the example shown in Figure 66, posts were erected before and after the crossing to ensure that no cars can be parked there.

If sight distances cannot be improved, Staplin et al. (2001) suggest increasing the perception reaction time (PRT) for traffic signs to 3 or, at the very least, 2.5 seconds.

Figure 67 shows some improvements for older drivers at an intersection with traffic lights. The improvements implemented there are:

- Advance warning signs
- Advance street name signs
- Additional lane control signs
- Backplates on signals to increase contrast and visibility of signals.

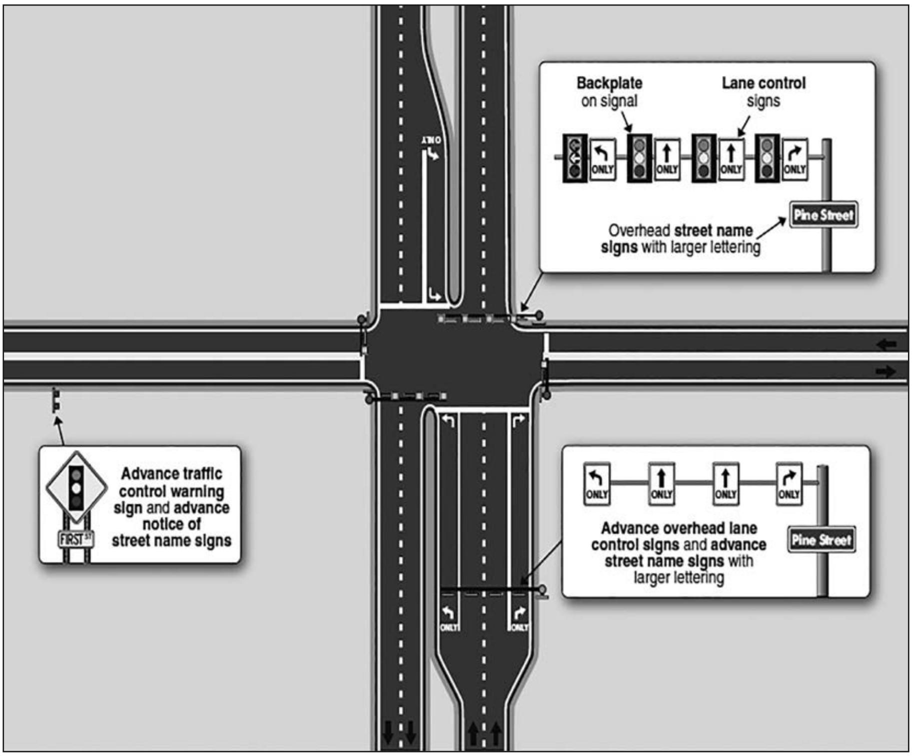

Figure 67: Improvements for older drivers at an intersection (source: GAO, 2007).

9.3.3 Signage and markings

Advanced warning or information signs are particularly important for older drivers because of their longer reaction times (Boenke & Gerlach, 2011a). Because older drivers have difficulty perceiving signs, specific care must be given to their needs. Because regulations differ between countries a comparison between younger and older drivers based on relative values is more helpful. Such a comparison was developed by Kline and Dewar (2004) (see Table 5).

Table 5: Relative legibility distance for symbol signs for different drivers and different light conditions (Kline & Dewar, 2004)

Age group	Lighting condition		
	Day	Night	Night/Glare
Young	1.00	0.70	0.69
Middle aged	0.88	0.60	0.60
Old	0.80	0.64	0.34

All drivers will benefit from an age-friendly design of signage and markings. An example of a situation in Dresden in which advanced information signs would be helpful is shown in Figure 68.

Regarding traffic signs, the Handbook gives some more specific recommendations:

- Sign size should be increased.
- The retroreflectivity level of the sign background should have specific values depending on the operating speed.

Figure 68: Traffic light concealed by bridge (lower half marked with yellow circle): Advance warning signs must be used in this situation (picture shows a situation in Dresden) (picture: Weller).

Besides retroreflectivity and letter size, colour and light contrast are important to compensate for older drivers' decrease in sensory perception (Giesa, 2004).

- The advance warning signs should be installed 2.5 seconds plus the brake reaction time before the actual sign or signal of interest.

Although warning signs are recommended the total number of signs should be limited to the necessary minimum. This minimum is the clear conveyance of the right-of-way regulation (Boltze, 2013).

Figure 69: Fifty shades of grey with low contrast make it difficult for older drivers to perceive their path. Curbs and tram paths should be coloured or equipped with retroreflective materials (picture shows a situation in Dresden) (picture: Weller).

Guidelines were developed in the British I'DGO project (Inclusive Design for Getting Outdoors) in terms of signage in general. Recommendations for signage were also developed as part of "The Design of Streets with Older People in Mind" work package.

- Keep consistence in the colour, shape, typeface and materials of signage to make it easily detectable, recognisable and readable by older people.

- Use appropriate size in texts for the street name signage with appropriate colour contrast in the signage itself and between the signage and the surroundings.
- Provide symbols and accompanying texts on maps and information boards avoiding information clutter to benefit not only older people but people with learning difficulties.
- Provide walking distance or time it takes to get to the destination wherever possible in sign with pointers.
- Although there is no common standard for where in the street signs should be positioned, preferably provide signage on both sides of the streets, at a suitable height and making sure that its view is not obstructed by vehicles or hidden by greenery. In addition, make sure that the signage do not obstruct the pedestrian flow or clutter the places.
- Keep consistency in standards and maintenance of signage to dis-encourage graffiti and vandalism. Older people are put off from using spaces by vandalism and graffiti." (cited from: http://www.idgo.ac.uk/)

In addition to signs, markings provide guidance on the road. As with signage, markings must fulfil the contrast requirements. They must further be in good condition which requires that their quality is checked regularly. Markings are especially relevant at large intersections with several potential turning paths. Each path must be marked in a way that allows the right path to be perceived from the line of sight of the driver. However, it must also be said that the guidebook (Staplin et al., 2001) recommends that markings are replaced by raised curbs that provide better guidance. The curbs shown in Figure 69 are in accordance with Staplin's recommendation (sloped curbs instead of barrier curbs) but additionally they must clearly be marked to avoid not being perceived (see also Boltze, 2013).

Besides signage for way finding and right-of-way, signage is also used to prevent wrong-way driving. In fact, because it seems that older drivers are over represented in this kind of driving error (Gerlach, Seipel, & Leven, 2012; SafetyNet, 2009) there has been some concern on how to sign the respective situations. Staplin et al. (2001) recommend the use of one-way signs often in a combination with do-not-enter signs. In Austria all highway exits are marked with highly visible do-not-enter signs to prevent drivers entering the motorway from the exit ramp (see Figure 70). Such signs are currently being evaluated in a German national project with test sites in Bavaria, and are similarly used in the Netherlands (van der Horst, 2012). Again, it should be noted that engineering measures that prevent entering the motorway from the wrong direction would be preferable to signs.

As well as markings rumble strips can be used as an engineering measure that helps drivers to stay inside their lane. Such measures also direct attention to the road and can be used prior to complex or dangerous situations (Noyce & Elango, 2004; Persaud, Retting, & Lyon, 2004; Räsänen, 2005).

Figure 70: Austrian do-not-enter sign used for motorway exits (picture: Weller).

9.3.4 Roundabouts

As has been stated above, intersections are particularly dangerous for older drivers, especially turning left. A measure that reduces the danger of having an accident when turning and that reduces accident severity is replacing at-grade intersections by roundabouts (Staplin et al., 2001). Roundabouts reduce the number of conflict points (see Figure 71). This measure was found to be highly successful: the number of accidents with injured persons was reduced by 50 % and the number of fatal

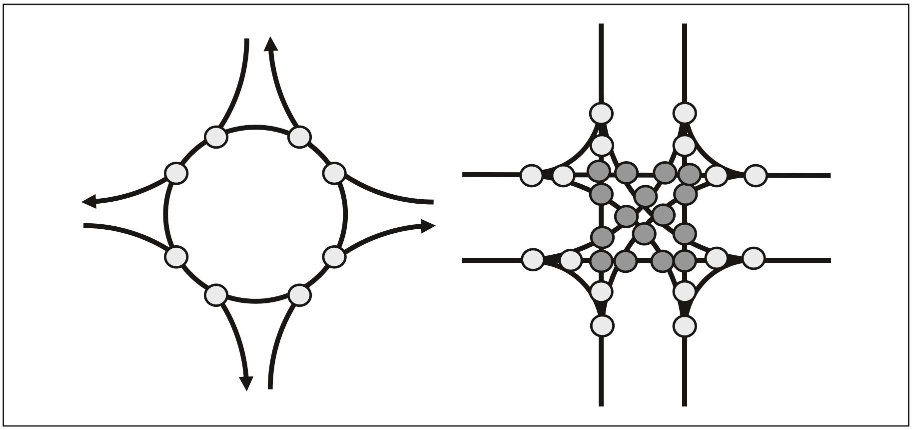
Figure 71: Conflict points at a roundabout and at a traditional at-grade intersection (source: Haller, 2007).

accidents was even reduced by 70 % (Elvik, 2003). Research shows that roundabouts reduce speed but do not necessarily diminish traffic flow (Lord, Schalkwyk, Chrysler, & Staplin, 2007). Despite roundabouts often being named as a safety measure for older drivers, there has been no hard evidence to prove that they benefit the most (Eby & Molnar, 2009).

Despite the overall increase in safety, it must be noted that “Studies show that older drivers are concerned about negotiating roundabouts (Lord, van Schalkwyk, Chrysler, & Staplin, 2007; Mesken, 2002), particularly ones that have multiple lanes.“ (cited from Eby & Molnar, 2009, p. 294).

9.3.5 Street lighting

Because older drivers have problems with visual perception at night (see Chapter 3 and Table 5), improving street lighting can benefit older drivers. However, especially for younger drivers, this measure might lead to safety-critical behaviour adaptation (Noland, 2001). However, despite negative side effects for a small group of drivers, it was shown that positive effects prevail. In a USA study, it was shown that overall safety increased strongly after lighting was introduced at intersections (FHWA, 1996). The Handbook suggests introducing lighting especially when crossing pedestrians are to be expected. It is supposed that street lighting has a positive effect on the overall mobility of older drivers (Schlag, 2003).

9.3.6 Implementation process of road design measures

As became obvious in the preceding chapters, implementing an age-friendly road design is an ambitious task. It might require additional resources compared to standard designs when the recommendations given for older drivers are stricter than the standard design. Thus, implementing age-friendly road design requires, to a large degree, convincing responsible administrative bodies of its effectiveness and efficiency. This should be easy to achieve given the change in demographics. Preusser et al. (1998) point out: “Whereas such devices involve significant cost in terms of dollars and travel delay, their cost-effectiveness may have to be revisited as the United States population continues to age.” (p. 151). This means that the efficiency of solutions must be evaluated anew against the background of demographic change.

However, in practice, convincing those responsible of the necessity to implement age-friendly road designs requires several steps. Such

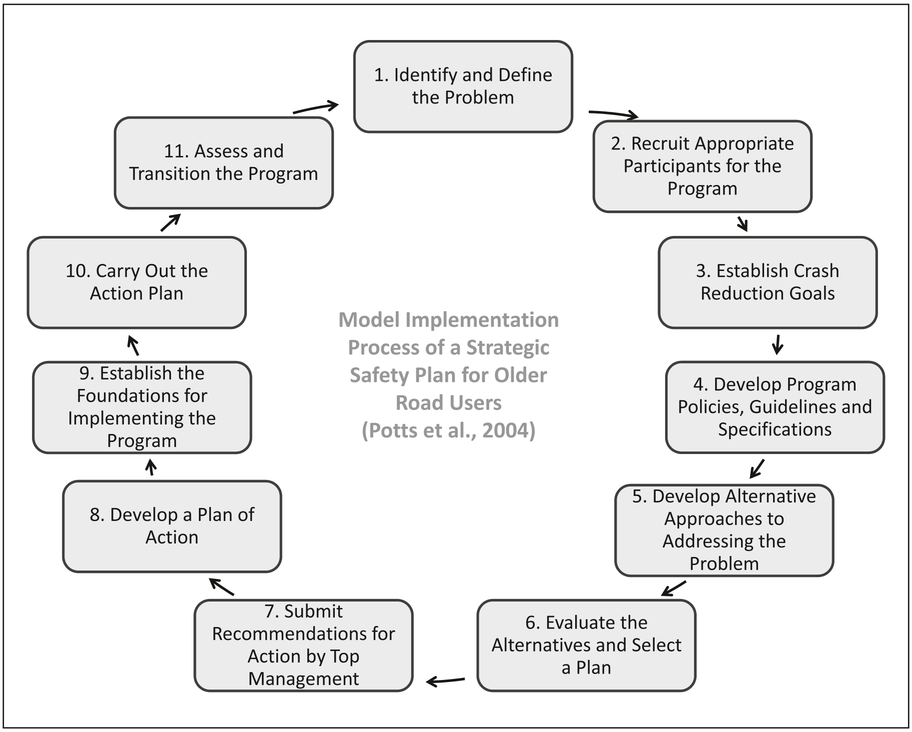

Figure 72: Model implementation process of a strategic safety plan for older road users (Potts et al., 2004).

steps are described and explained in Gerlach et al. (2007) and in Potts et al. (2004) (see Figure 72).

When considering costs and effectiveness one must always consider that age-friendly designs usually also support all other road users and thus increase safety and efficiency of the entire system (Boltze, 2013).

9.4 Vehicle design and technology

Traffic safety is influenced by the human, the vehicle and the environment. In terms of accidents, the vehicle itself initially seems to play a minor role and is to blame (either solely or in combination with other factors) in only 15 % of cases (Treat et al., 1977, cited in Weller et al., 2006).

This low percentage is due to the high technical reliability of the vehicle. However, because the vehicle can be seen as the interface between driver and environment, there is tremendous potential to increase safety and comfort, particularly for older drivers.

There are two main sources to increase driver comfort and safety with vehicles:

- Supportive automotive design including age-friendly access and human-machine-interfaces (HMI)
- New technologies such as advanced driver assistance systems (ADAS), and warning and information systems.

This chapter was written along these two thematic areas.

9.4.1 Supportive automotive design

Using an automobile starts with getting in and ends with getting out of a vehicle. Whereas this is no problem for younger drivers it is a topic of great concern for older drivers (Engeln & Moritz, 2013; Herriotts, 2005). In the study by Herriots (2005) among more than 1000 older car drivers the subsequent car features were named as causing problems when getting in ("in) or getting out ("out") of the car (see Table 6). Of the older drivers asked, more than one third experienced problems when getting out of and about one quarter experienced problems when getting into the car.

Table 6: Car features causing problems to those older drivers experiencing difficulties getting in and out (Herriotts, 2005)

Car feature	In	Out
Sill	37.8	43.4
Seat cushion	31.1	25.7
Cant rail/roof top	16.3	11.8
Steering wheel	16.3	10.8
Door	12.7	19.8
Seat other	10.4	8.3
A-pillar	8.8	9.4
Fascia/dashboard	4.8	4.9

Although there have been notable design changes since 2005, Engeln and Moritz (2013) found in their recent study that getting in and out of the car is still a major concern for older drivers and passengers. Eby and Molnar (2009) assume that the lack of an age-friendly vehicle is the result of insufficient research regarding the needs of older adults. However, as early as 2001, the OECD named age-friendly car access dimensions in their publication on Aging and Transport (OECD, 2001a) (see Table 7).

Table 7: Recommended car access dimensions (Institute of Consumer Ergonomics, 1985; Petzäll, 1991, both cited in OECD, 2001a)

Car feature	Recommended dimension (cm)
Door frame height above ground	133-138
Width of door aperture (A to B pillar)	80-100
Seat height above ground	50-60, 50 optimum
Doorsill height	36-40
Doorsill to car floor	4-9, 6 optimum
Seat front edge to A pillar	35-45
Door opening angle	70°, 90° when assistance needed

Some measures that could be taken to ease getting in and out of the vehicle:

- To support drivers, the door sills should be lowered. This can be restricted to entering and leaving the car in standstill.
- Similarly, the cant rail or parts of the car roof in general could be lifted to increase headroom.
- Furthermore, the seats should support the driver when getting in and out. This could be achieved with the help of motors which are already integrated as part of the seating comfort.
- The fact that the steering wheel can already be adjusted in most high-end cars certainly helps getting in and out comfortably.
- Doors should be designed with an increased opening angle that gives additional moving space. (However, it must also be assured that dimensions of car parks and parking zones allow such doors to be opened.)
- Finally, thought should be given to designing age-friendly fascia/dashboard-dimensions that are outside the moving perimeter when entering and leaving the car.

Besides getting in and out of the car, sight characteristics are very important because they determine the amount of visual information that are perceptible to the driver. Especially the characteristics of the rear window and of the pillars determine the size of the field-of-view (Fosberry, 1958). Improving sight without electronic devices can be achieved with improved side mirrors. Mortimer (1989) suggested using automated headlamp alignment and beam patterns that emphasize glare control. The German Road Safety Council (DVR) recommends the use of Xenon (HID) lights for older drivers because of their better sight characteristics (DVR, 2009). However, one must also say that – at least some time ago – there was concern that especially older drivers are negatively affected by HID lights (Mainster & Timberlake, 2003).

There is evidence that automatic transmission improves driving behaviour of older drivers (Selander, Bolin, & Falkmer, 2012), particularly the driving error "too fast for the situation" decreased with automatic transmission. For a younger comparison group, no improvement effects were found which indicates that particularly older drivers benefit from the system. Thus, the authors give a clear recommendation in favour of automatic transmission for older drivers.

Another area of major concern is the presentation of information in the car. Information can be beneficial for decision making but also has the potential to be a source of distraction itself. This affects older drivers but is also a concern for all drivers and as such some general design principles are named first. Wickens, Lee, Liu, and Becker (2004) developed 13 such design principles. These principles are grouped in thematic groups:

- Perceptual principles
  - Make displays legible (or audible).
  - Avoid absolute judgment limits.
  - Top-down processing (i.e. take into account the user's past experiences)
  - Redundancy gain (see the "Zwei-Sinne-Prinzip" ("Two-senses principle")
- Mental model principles
  - Principle of pictorial realism (see Figure 73)
  - Principle of the moving part (actual movement and direction should be represented by display elements showing respective movement and direction)
- Principles based on attention
  - Minimizing information access cost (see also the "effort" part in the SEEV model (Wickens & McCarley, 2008)
  - Proximity compatibility principle (see also Gestalt principles)
  - Principle of multiple resources (use different modalities when there is a risk of information overload in one modality)
- Memory principles
  - Replace memory with visual information: knowledge in the world (when there is a danger of memory overload, provide the information externally)

– Principle of predictive aiding (e.g., show an intersection on a navigation display ahead of actually seeing it)
– Principle of consistency (information should be presented in a similar fashion across different displays).

Küting and Krüger (2002) have named similar principles with respect to in-vehicle display design for older drivers. Of course, all principles comply with the standards set by the European Commission (2007). Design principles specifically related to older people were recently summarized in a SWOV report (SWOV, 2010b) (see Table 8).

Table 8: Functional limitations and relevant design principles for an age-friendly control-panel design (based on Caird et al., 1998; Gardner-Bonneau & Gosbee, 1997, cited in SWOV, 2010)

Functional limitations	Relevant design principles
General sensory deficits	Use redundant cues, like auditory, visual and tactile feedback
Visual acuity (close by)	Increase character size of text labels
Colour vision	Use white colours on a black background
Diminished low-light vision	Use supplemental illumination for devices used in low-light conditions
Sensitivity to glare	Use matt finishes for control panels and antiglare coating on displays
Hearing	Use auditory signals in the range of 1500-2500 Hz.
Contrast sensitivity and depth perception	Where depth perception is important, provide non-physical cues, such as relative size, interposition, linear position and texture gradient
Selective attention	Enhance the conspicuousness of crucial stimuli through changes in size, contrast, colour or motion
Perception-reaction time	Give the user sufficient time to respond to a request by the system and provide advanced warnings to provide the driver with enough time to react to the on-coming traffic situation
Hand dexterity and strength	Use large diameter knobs, textured knob surfaces and controls with low resistance

Owsley, McGwin, and Seder (2011) conducted focus group among older drivers regarding their opinion on dashboard information design in vehicles. It was found that there was considerable disagreement between the older drivers (for example, regarding the use of text-labels versus icons) and some of the recommendations in Table 8 were not regarded as being particularly important such as the use of contrast and letter size. The authors of this study attribute this to the visual health of the participants which was still good. However, agreement on a larger scale was found in favour of removing instruments from the dashboard that are not often needed and of easy access to the hazard light button. The participants also agreed that the steering wheel should not obstruct information on the dashboard.

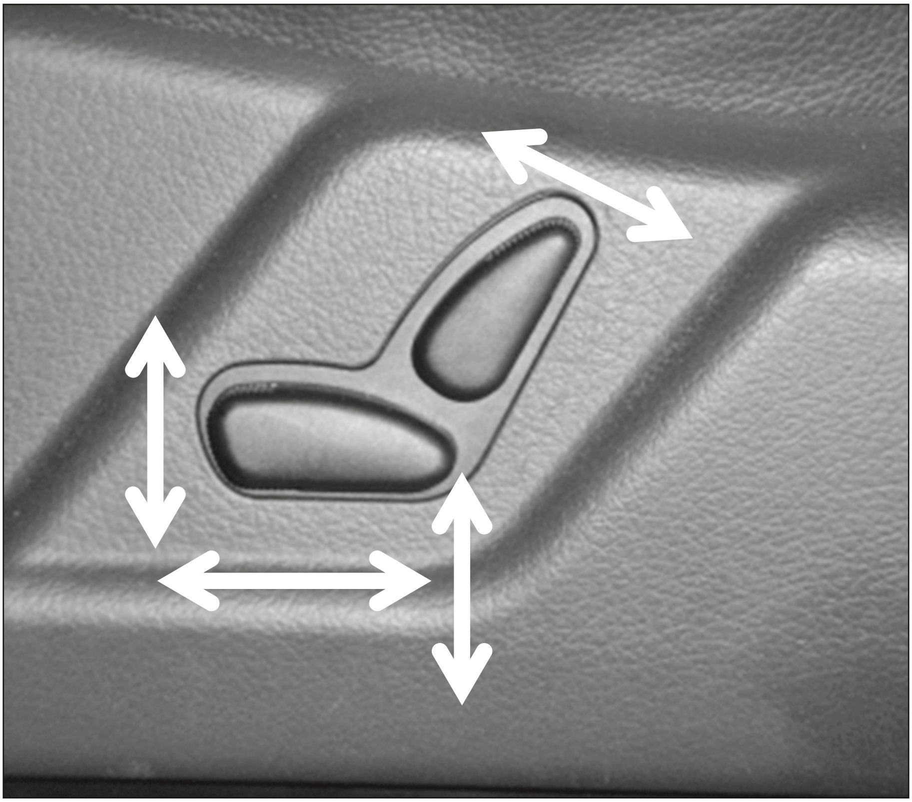

Figure 73: Pictorial realism: the switch used to adjust the car seat looks like the car seat which can be adjusted by the respective switch elements (arrows used to indicate direction of switch and respective seat movement) (picture: Weller).

So far, most of the recommendations have concerned visual display. However, it has already been pointed out that there is a redundancy gain by also presenting information in other modes, especially auditory. In fact, because driving is a predominantly visual task, providing auditory information is a good alternative. Baldwin (2002) summed up principles for auditory information presentation. These were originally developed for Intelligent Vehicle Highway Systems (IVHS) but are applicable for all other auditory in-vehicle information:

1. “Use the auditory channel for presenting essential collision avoidance warnings and navigational information to avoid overloading the visual processing abilities of older drivers, to reduce task switching time and periods of time when drivers are required to take their eyes off the road.

2. The presentation level (PL) of verbal displays for use by older drivers with normal hearing abilities for their age group should be at least 10 dB above the level adequate for younger drivers.

3. Ensure that auditory presentation levels (PLs) are at least +6 dB above background noise levels and preferably +15 dB S/N for drivers experiencing mild hearing impairment.

4. Make use of context to aid comprehension, preferably at the beginning of the voice message. For example: `Turn ahead: Left onto Hampton’, would be preferable to `Left on Hampton ahead’.

5. Use list form messages rather than prose form or complex messages.

6. Use standard signage and terminology when possible, and consistent formatting across display situations.

7. Keep message length to no more than three content items.

8. Use digitized natural speech rather than synthesized speech and avoid extensive speech compression.

9. Provide navigational information well in advance of driving manoeuvres to allow older drivers more time to process the information and plan manoeuvres.” (Baldwin 2002, pp. 323-324).

9.4.2 In-Vehicle Information Systems (IVIS) and Advanced Driver Assistance Systems (ADAS)

In-Vehicle Information Systems (IVIS) and Advanced Driver Assistance Systems (ADAS) were both only made possible by the vast progress in computer technology. Their information and potential for action would not be possible without fast reaction to user input or situational changes. The amount of systems available on the market has increased during the last couple of years. Some of these systems are extremely successful such as the Electronic Stability Control (ESC) which was recently made mandatory for new cars in the European Union (SWOV, 2010a). Although ADAS were not named in the OECD publication on older drivers (OECD, 2001a) they are now standard, especially with respect to older drivers.

There are several ways how to categorize such systems. One classification is based on when they are active in relation to normal driving and an accident (see Figure 74). Another way to categorize IVIS and ADAS is based on how they interact with the driver and whether the driver is responsible or not (see Figure 75). Other classifications are given in Golias, Yannis, and Antonioul (2002) and Wallentowitz and Neunzig (2005).

Guo, Brake, Edwards, Blythe, and Fairchild (2010) give an overview of systems that are particularly relevant for older drivers (see Table 9). Further information on ADAS which is particularly suitable for older drivers can also be found in Eby and Molnar (2009).

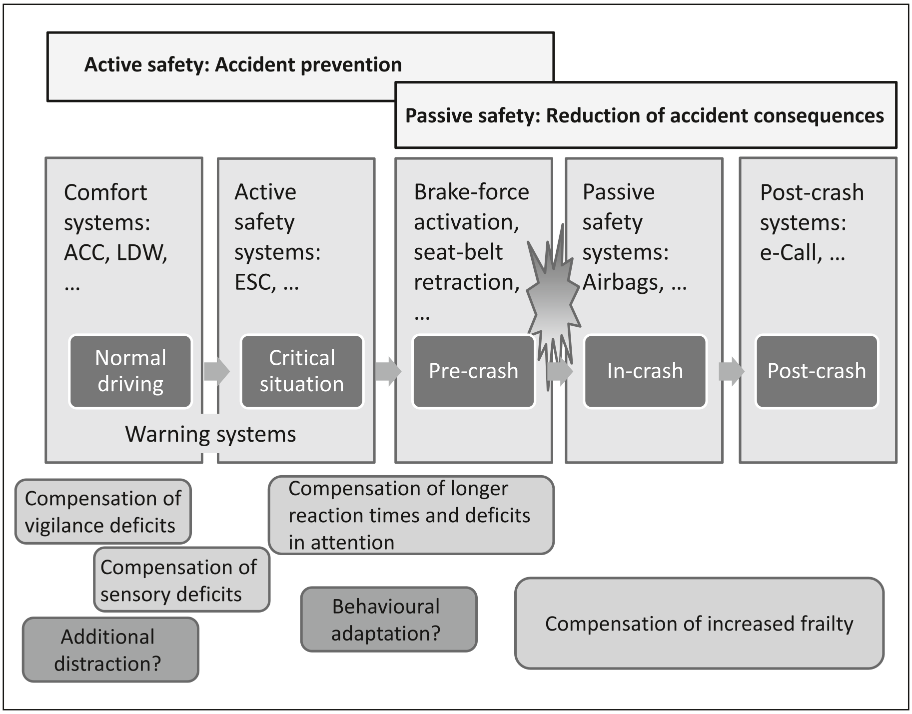

Figure 74: Categories of ADAS and potential positive and negative effects for older drivers (source: SaMERU, 2013).

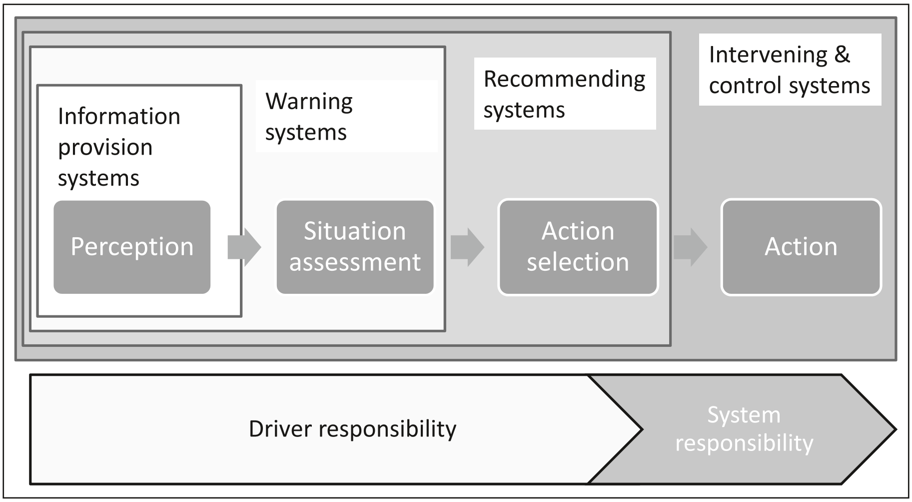

Figure 75: Categories of Driver Assistance Systems and responsibility (based on Donges, 1999; Prokop et al., 2012).

Table 9: Driver support systems for elderly drivers (based on Guo et al., 2010)

Driver support systems	Assistance to elderly drivers
Adaptive Light Control (ALC)/Adaptive Front Lighting System (AFS)	Increase visibility at night and in bad weather; offer a better view of the road ahead, including other vehicles and obstacles in the distance.
Lane Departure Warning (LDW)	Alert the driver to drive within the lane when deviation occurs.
Intersection Assistant	Alert the driver to stop for the traffic from the right or offer speed suggestions according to the road signs/traffic signals, and then warn the driver if he/she performs inappropriately.
Lane Change Assistance (LCA) or Blind Spot Detection (BSD)	Warn the driver visually/audibly to avoid overtaking in critical situations.
Obstacle and Collision Warning (OCW)	Warn the driver when vehicles, cyclists, pedestrians or other obstacles on the road ahead are detected; prepare the vehicle for an imminent collision proactively to avoid the collision and/or mitigate the severity.
Intelligent Speed Adaptation (ISA)	Help the driver maintain a safe speed by alerting the driver (advisory ISA) or decelerating automatically in cooperation with traffic management systems (voluntary ISA) when the speed limit for a given road is exceeded.
Electronic Brake Assist System (EBS)	Take over the activity from the driver to avoid an accident or decrease vehicle speed at the moment of collision in order to reduce its seriousness.
Adaptive Cruise Control System (ACC)	Take over the activity from the driver to keep a safe distance from the vehicle ahead and avoid collision. The driver can override the system at any time.

Table 10: Relative weaknesses of older drivers and potential ADAS to compensate these weaknesses (Davidse, 2007)

Relative weaknesses	In-vehicle assistance systems
Contrast sensitivity and motion perception	Collision warning systems for intersections Automated lane changing and merging systems
Peripheral vision and flexibility of head and neck	Automated lane changing and merging systems Blind spot and obstacle detection systems
Selective attention	In-vehicle signing systems Special intelligent cruise control
Speed of information processing, divided attention, and performance under pressure of time	Systems that give information on the characteristics of complex intersections the driver is about to cross

Only the last three systems are control systems that actively control longitudinal control. All other systems involve some kind of information and warning that must be conveyed to the driver. Davidse has similarly juxtaposed older drivers' relative weaknesses and ADAS (see Table 10). In this list, control systems prevail but information and warning systems are also regarded as being highly relevant.

Some of these systems will now be discussed in more detail. However, before introducing and discussing warning and control systems, vision enhancement systems will be discussed.

Vision Enhancement Systems (VES) can be classified as information provision systems. However, they differ from the majority of systems in this category in that they do not always present additional information but rather compensate for night-time light conditions. VES make use of different technologies and are based on an improvement of the lighting conditions of the vehicle and the road ahead. Different sensors and GPS data are used to adjust the light beam to the environment ahead. Depending on position, steering wheel movement and road category, the light beam is automatically adapted to provide the best view ahead and to relevant objects. Such systems can compensate for age-related declines in sensory perception (DVR, 2009; Färber, 2000).

A further development is Night Vision Systems (NVS). These systems are not simply based on an adjustment of the headlight beam but make use of additional technology such as infrared. The electronic image created by these systems can be projected in real-time in the car, thus increasing the perceptibility of dangers outside the car. However, the effectiveness of such systems depends largely on their characteristics.

Mahlke, Rösler, and Seifert (2007) compared six different VES and found one to be particularly effective and efficient as well as being rated positively by experts. This system was a far infrared sensor with automatic pedestrian recognition and an event-based LED display. The characteristics which the authors of this study assume to be responsible for this positive effect can also serve as a guideline for an age-friendly design of VES:

- “The system is very easy to learn. Because it presents information in a highly intelligible way, neither extensive instructions nor training are required for interpreting its output.

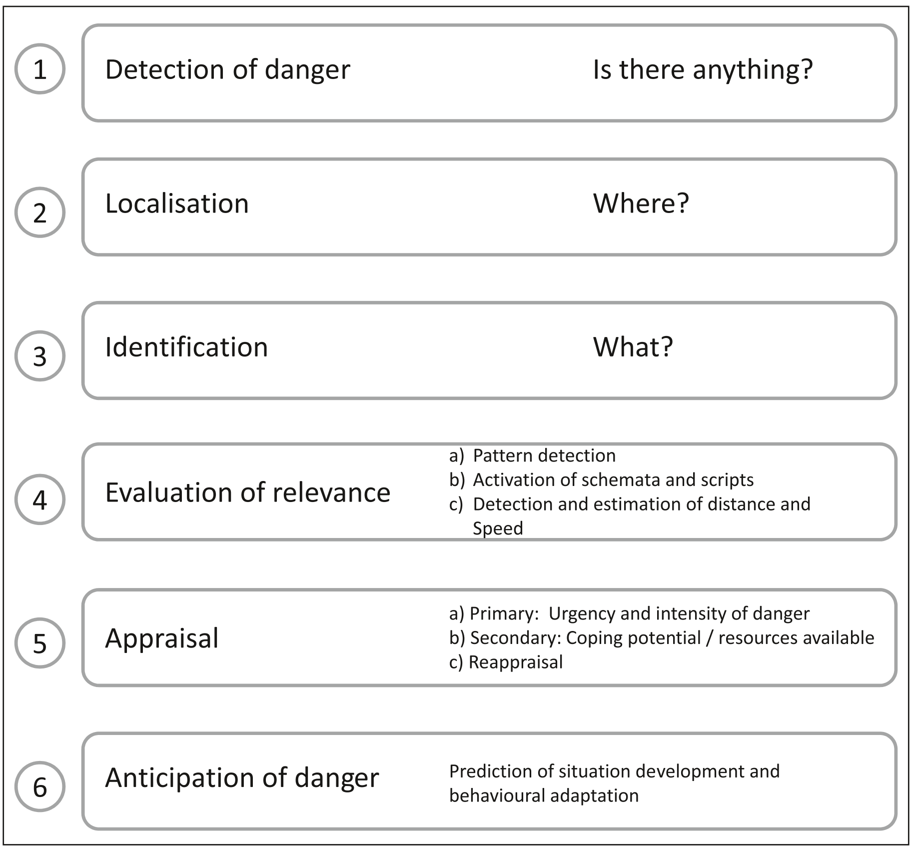

Figure 76: Step-model of the cognition of danger (Schlag, 2008, cited in Schlag, Petermann, Weller, & Schulze, 2009).

- Hazardous events are detected and signalled automatically. The event-based character of system responses relieves drivers from the burden of continuously scanning a display in addition to driving.
- The unobtrusive location of the system avoids blocking central parts of the visual field. Its LED display can be perceived peripherally and draws attention only when necessary." (Mahlke et al., 2007, p. 529)

Some of the systems compared by Mahlke et al. (2007) can be classified as information or as warning systems because they present additional information to the driver and preselect and highlight potential dangers. These systems are helpful because they support the driver in some or even all steps of danger-cognition (see Figure 76).

The specific benefit of information and warning devices for older drivers is shown in Figure 77: an early and step-by-step presentation of information gives older drivers more time to select the relevant information and to process this information (Küting & Krüger, 2002). The complex traffic situation named in Figure 77 could be an intersection. In this case, one could display the following information:

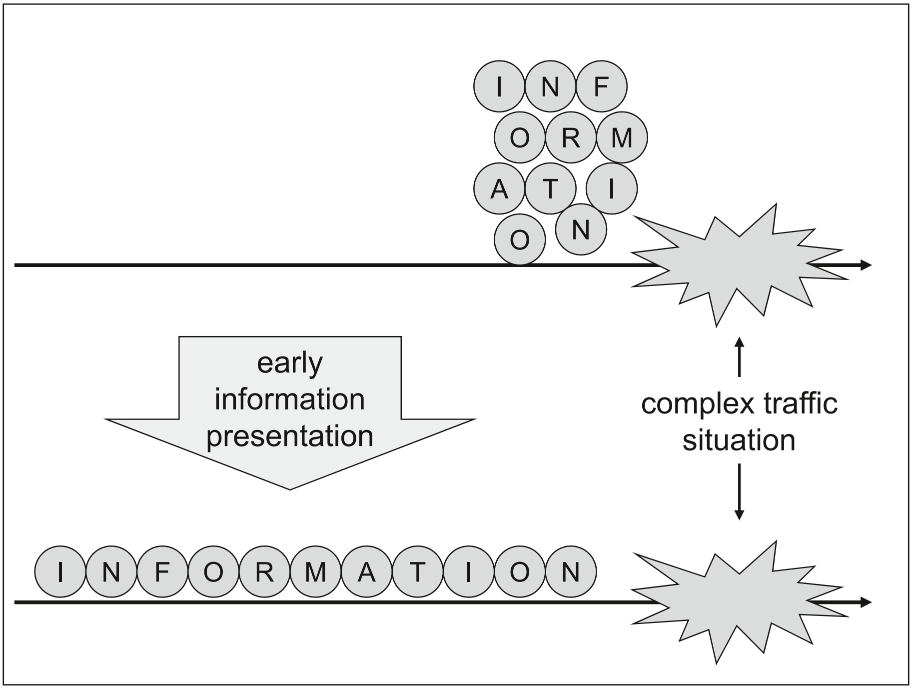

Figure 77: Concept of support for coping with complex traffic situations (Küting & Krüger, 2002).

- right-of-way regulations
- direction information
- information on other participants when changing lane or merging
- speed information
- extraordinary conditions such as accidents or local road conditions

However, this principle of information presentation is mainly only applicable to information that is static. Up-to-date warnings are usually time-critical and need to be presented at the time the danger is detected. Examples of such warning systems are lane departure warnings and lane change assistants which usually also give a warning when the adjacent lane is occupied by another vehicle. Lane departure warnings send a signal (visual, haptic, acoustic) whenever they detect that the driver leaves their lane. In fact, Buld et al. (2006) found that older drivers have more problems staying within their lane.

Lane change assistants can be even more beneficial to older drivers. This is because older drivers have tremendous problems turning their head. In a recent study at TU Dresden, Weller et al. (2013) found that older drivers perform hardly any over-shoulder checks (see Figure 13). Although, in this study, drivers claimed that the reason was that they regularly checked their mirrors and thus knew when other vehicles would be coming, no differences in mirror-checks were found to a younger comparison group. Buld et al. (2006) found that older drivers did not see vehicles in the adjacent lane. This indicates that older drivers could benefit the most from a lane change assistant. The information in existing systems is presented in the side mirrors and is thus where the driver needs it without distracting the driver.

Systems that are less time critical are parking assistance and navigation systems. In the study by Herriotts (2005) over half of older drivers experienced problems when turning around and looking out of the rear window. This result is not surprising given decreased motor mobility, especially decreased neck mobility. However, it is remarkable how little concern was given to this condition in the past. Now, with modern parking assistance systems, drivers are guided with acoustic signals and rear view cameras. Even automatic parking is available. Again, a word of caution must be given. This is because the information presented when parking is usually given on the dashboard. This is in the opposite direction of where the information comes from and is thus counter-intuitive and can lead to confusion (Färber, 2000).

Navigation systems are still sold separately and are not standard in most modern vehicles. However, as studies have shown (Dingus et al., 1997; Jakobs & Ziefle, 2011), older drivers benefit the most from such modern navigation systems. This is especially the case for those who still feel comfortable enough to travel longer distances or to unknown destinations. It must be said that navigation systems that are put into the car as an additional device ("nomadic device") and that are attached to the windscreen or the dashboard can obstruct the field of view and that can be safety critical as well as posing potential distraction effects. Thus, the best way to present navigation information would be to do so in a head-up display (HUD). Recent studies showed that navigation information could even be presented as tactile information (Gustafson-Pearce, Billett, & Cecelja, 2007).

Another category of systems deals with speed. Intelligent speed systems can derive information on the current speed limit from position information and by recognizing speed limit signs. Additional speed information, such as the appropriate speed for a given road segment can be derived from databases with information on the road geometry. Such systems can either be information systems or they can be control systems (Intelligent Speed Adaptation – ISA). Carsten and Tate (2005) showed that ISA would save significant costs and would dramatically increase road safety. However, given the low acceptance of such systems, it seems that society does not want to trade individual free speed selection for collective safety. Although older drivers usually do have fewer problems with inappropriate speed, research has found that they nevertheless do have some problems (Selander, Lee, Johansson, & Falkmer, 2011) and might also benefit from such systems. Another positive effect for older drivers would be a lower and more homogenous speed.

A system that integrates a variety of systems is the intersection assistant. These systems help older drivers in the situation that is most dangerous for them, namely intersections (see Chapter 8.2.2). Therefore, assisting them in these situations is a promising strategy to increase older drivers' safety and comfort. However, intersection assistants do not currently exist with full functionality but are being developed. Despite this, some preliminary evidence of their effects is available from simulator studies.

Dotzauer, Caljouw, de Waard, and Brouwer (2013) evaluated an intersection assistant that gave advice whether it was safe to cross an intersection by displaying a green, amber or red light in the head-up display (HUD). The experimental sample consisted of older drivers who either drove with or without the assistant. The authors found an overall positive effect with faster and safer crossings when using the assistant. However, indications were also found that the drivers who completed several trials with assistance showed potentially safety-critical behavioural adaptation in a subsequent trial without the system.

Becic, Manser, Drucker, and Donath (2013) evaluated an advanced intersection assistance system called "Cooperative Intersection Collision Avoidance System-Stop Sign Assist (CICAS-SSA)" with and without an additional 1-back distraction task for younger and older drivers. The study which was conducted in a simulator did not find any negative effects but rather a more conservative driving style, that is, older drivers took longer to cross and selected fewer critical gaps. The simulated system provided the information on whether a gap was safe to cross in the respective side mirror.

Ziefle, Pappachan, Jakobs, and Wallentowitz (2008) found that a simulated intersection assistant was rated very positively by older drivers (less so by younger drivers) and that an auditory system was preferred when compared to a system with visual information on an additional display.

These studies show an overall positive effect of intersection assistants but also reveal that their effect on older drivers depends on their design. The questions to be answered are similar to the ones discussed above regarding display design:

- How should the information be presented (visual, haptic, acoustic)?
- Where should the information be presented?
- Which information should be presented (dichotomous safe/unsafe or exact values)?

However, once these questions are answered, these systems have a tremendous potential to increase older drivers' safety.

A final category of modern systems which would particularly help older drivers are eCall systems. These systems are only activated after a crash (see Figure 74) and send information on the position of the crashed vehicle to an emergency call centre (public safety answering point, PSAP) where it is received and forwarded to local emergency services.

The positive effect of eCall is mainly based on the time saved until an emergency service arrives at the location of the crash. Additionally, individual needs of specific medication can also be sent provided the driver consents to this. Recently, the European Commission has published recommendations paving the way for a Europe-wide introduction of eCall (European Commission, 2011a). From 2015 eCall is mandatory in new vehicles in Europe (European Commission, 2013).

Although there is ample agreement that ADAS are beneficial for road safety in general and for older drivers in particular, there is still some justified concern regarding potential negative side effects. Some of these particularly relevant for older drivers are summarized in Meyer (2009):

- Misperception of system limitations
- Learning new skills and new systems becomes increasingly difficult with age.
- The willingness to learn, understand and adapt to new systems might decline with age.
- Drivers must change well-established behavioural patterns/routines. An example would be camera assisted backing: Although this system will greatly support older drivers because they do not have to turn their head, the direction of sight completely changes.
- Distraction
- Automation bias/complacency

These concerns are shared by Eby and Molnar (2012) who point out that "… there is some evidence suggesting that older adults may lack knowledge about how some safety features work and may misunderstand their effectiveness in protecting vehicle occupants." (p. 41).

Some of these aspects have their origin in a paradox described by Meyer (2009): "New in-vehicle systems create particular challenges for older drivers. Paradoxically, even though older drivers may find it more difficult to use these devices, they are likely to be the first to encounter them, because innovations are often initially introduced into high end cars, which are usually bought by more affluent (and usually older) costumers. Thus, the more mature driver population is often the first to encounter still immature systems." (Meyer, 2009, p. 23).

In order to prevent negative side effects, the European Commission developed principles on safe and efficient in-vehicle information and communication systems (European Commission, 2007). The relevant principles are listed below, explanations and examples for each principle are given in the original document.

- "Overall design principles
  - The system supports the driver and does not give rise to potentially hazardous behaviour by the driver or other road users.
  - The allocation of driver attention while interacting with system displays and controls remains compatible with the attentional demand of the driving situation.
  - The system does not distract or visually entertain the driver.
  - The system does not present information to the driver which results in potentially hazardous behaviour by the driver or other road users.
  - Interfaces and interface with systems intended to be used in combination by the driver while the vehicle is in motion are consistent and compatible.
- Installation principles
  - The system should be located and securely fitted in accordance with relevant regulations, standards and manufacturer instructions for installing the system in vehicles.
  - No part of the system should obstruct the driver's view of the road scene.
  - The system should not obstruct vehicle controls and displays required for the primary driving task.
  - Visual displays should be positioned as close as possible to the driver's normal line of sight
  - Visual displays should be designed and installed to avoid glare and reflections.
- Information presentation principles
  - Visually displayed information presented at any one time by the system should be designed such that the driver is able to assimilate the relevant information with a few glances which are brief enough not to adversely affect driving.
  - Internationally and/or nationally agreed standards relating to legibility, audibility, icons, symbols, words, acronyms and/or abbreviations should be used.
  - Information relevant to the driving task should be accurate and provided in a timely manner.
  - Information with higher safety relevance should be given higher priority.

  - System generated sounds, with sound levels that cannot be controlled by the driver, should not mask audible warnings from within the vehicle or the outside.
- Interface with displays and controls
  - The driver should always be able to keep at least one hand on the steering wheel while interacting with the system.
  - The system should not require long and uninterruptible sequences of manual-visual interfaces. If the sequence is short, it may be uninterruptible.
  - The driver should be able to resume an interrupted sequence of interfaces with the system at the point of interruption or at another logical point.
  - The driver should be able to control the pace of interface with the system. Specifically, the system should not require the driver to make time-critical responses when providing input to the system.
  - System controls should be designed such that they can be operated without adverse impact on the primary driving controls.
  - The driver should have control of the loudness of auditory information where there is likelihood of distraction.
  - The system's response (e.g. feedback, confirmation) following driver input should be timely and clearly perceptible.
  - Systems providing non-safety related dynamic visual information should be capable of being switched into a mode where that information is not provided to the driver.
- System behaviour principles
  - While the vehicle is in motion, visual information not related to driving that is likely to distract the driver significantly should be automatically disabled, or presented in such a way that the driver cannot see it.
  - The behaviour of the system should not adversely interfere with displays or controls required for the primary driving task and for road safety.
  - System functions not intended to be used by the driver while driving should be made impossible to interact with while the vehicle is in motion, or, as a less preferred option, clear warnings should be provided against the unintended use.
  - Information should be presented to the driver about current status, and any malfunction within the system that is likely to have an impact on safety.

- Information about the system
  - The system should have adequate instructions for the driver covering use and relevant aspects of installation and maintenance.
  - System instructions should be correct and simple.
  - System instructions should be in languages or forms designed to be understood by the intended group of drivers.
  - The instructions should clearly state which functions of the system are intended to be used by the driver while driving and those which are not.
  - Product information should be designed to accurately convey the system functionality.
  - Product information should make it clear if special skills are required to use the system as intended by the manufacturer or if the product is unsuitable for particular users.
  - Representations of system use (e.g. descriptions, photographs and sketches) should neither create unrealistic expectations on the part of potential users nor encourage unsafe use."

In addition to these principles, there are a number of standards developed by the ISO's Technical Committee 22 (Steering Committee 13 "Ergonomics applicable to road vehicles") which are relevant for the design of in-vehicle information presentation:

- ISO 2575:2010: Road vehicles -- Symbols for controls, indicators and tell-tales
- ISO/TR 12204:2012: Road vehicles -- Ergonomic aspects of transport information and control systems -- Introduction to integrating safety critical and time critical warning signals
- ISO/TS 14198:2012: Road vehicles -- Ergonomic aspects of transport information and control systems -- Calibration tasks for methods which assess driver demand due to the use of in-vehicle systems
- ISO 15005:2002: Road vehicles -- Ergonomic aspects of transport information and control systems -- Dialogue management principles and compliance procedures
- ISO 15006:2011: Road vehicles -- Ergonomic aspects of transport information and control systems -- Specifications for in-vehicle auditory presentation
- ISO 15008:2009: Road vehicles -- Ergonomic aspects of transport information and control systems -- Specifications and test procedures for in-vehicle visual presentation

- ISO/TR 16352:2005: Road vehicles -- Ergonomic aspects of in-vehicle presentation for transport information and control systems -- Warning systems
- ISO/TS 16951:2004: Road vehicles -- Ergonomic aspects of transport information and control systems (TICS) -- Procedures for determining priority of on-board messages presented to drivers
- ISO 17287:2003: Road vehicles -- Ergonomic aspects of transport information and control systems -- Procedure for assessing suitability for use while driving

Within the United Nations Economic Commission for Europe (UNECE) working group WP29 “World Forum for Harmonization of Vehicle Regulations” is also developing “Guidelines on establishing requirements for high-priority warning signals” (UNECE, 2010).

Because information overload is particularly a problem for older drivers, Färber (2002) strongly recommends two things:

- Information management must be implemented in cars to avoid information overload (see Piechulla, Mayser, Gehrke, and König, 2003 for an example).
- Older users must be involved in the design process.

Färber (2002) further demands that older drivers’ performance with a vehicle and its components should be the test criterion against which these should be tested: if they succeed for older drivers they will succeed for all drivers – at least in terms of safety. This claim is shared by Young and Bunce (2011) who point out the necessity to have a user-centered approach when designing ADAS for older drivers. Also Eby and Molnar (2012) conclude that the time has come to design an age-friendly vehicle.

10 The decision to stop driving

A review of the literature documenting the topic of giving up driving shows that there are several common findings but also some differences between studies. Perhaps the most common finding is that there is a large gender-difference with females giving up driving earlier than men, see Figure 78 (Brabyn, Schneck, Lott, & Haegström-Portnoy, 2005).

In the study by Brabyn et al. (2005) age and gender together explained 27 % of the variance in the decision to stop driving with two other groups of variables explaining another 10 %. These two groups were self-reported serious health problems and self-reported inattention and inexperience errors when driving. Problems in non-driving related activities were not related to the decision to stop driving.

Johnson (2008) reported that the perception of the decline in physical functioning and/or involvement in a nonfatal accident predicted driving cessation in a sample of older rural woman.

Gender differences were also found by several other authors (Hakamies-Blomqvist & Wahlström, 1998; Oxley, Charlton, Scully, & Koppel, 2010; Rimmö & Hakamies-Blomqvist, 2002). Given the younger age of female drivers who stopped driving, it is not surprising that they are in better health when doing so (Oxley et al., 2010).

A longitudinal study found that processing speed was associated with driving cessation together with age and days driven per week at the baseline assessment (Edwards, Bart, O'Connor, & Cissell, 2010).

Among the health reasons given, visual ability was most often cited as the reason for giving up or limiting driving (Ragland, Satariano, & MacLeod, 2004). Nonmedical reasons often cited in this study were being concerned about an accident, being concerned about crime, and having no reason to drive.

In a recent study, cognitive impairment was also found to be associated with driving cessation (Kowalski et al., 2012). However, in this study, it was also found that among those participants who were still driving, the amount of cognitive impairment was not associated with planning to stop driving.

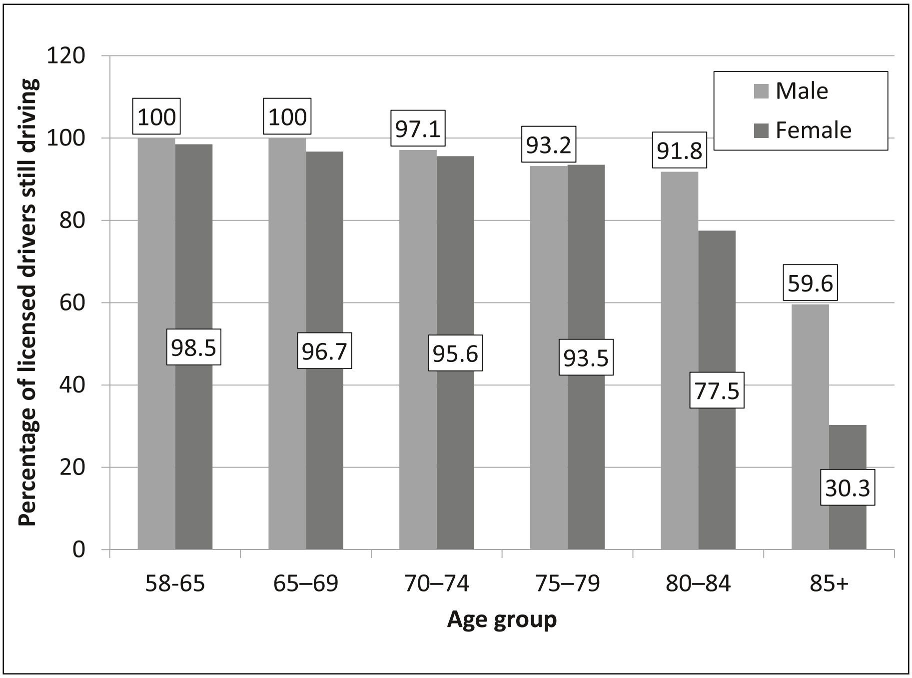

Figure 78: Age-dependent gender differences in driving cessation despite possessing a license (based on Brabyn et al., 2005).

Although health is an important factor it is obviously not sufficient to stop driving. As an example, Ramulu et al. (2009) found that, although driving cessation was related to glaucoma, more than 50 % were still driving despite having bilateral glaucoma.

It seems that the relationship between giving up driving and health condition declines when more severe health conditions such as dementia are involved. Carr, Shead, and Storandt (2005) compared two groups of elderly people with dementia and found that the group still driving did not differ in their cognitive ability from the group that stopped driving. This indicates that other internal or external reasons than just the amount of impairment alone influence the decision.

Similar results were found in the PRODEM study in Austria (Seiler et al., 2012): Although the group with dementia that ceased driving did significantly differ in a number of cognitive tests from the group that continued driving, both groups could not be distinguished in a multivariate analysis on the basis of cognitive performance alone. In this study the estimate of risk made by the caregivers was the most important predictor of driving cessation.

As well as the reasons named above it must also be said that driving cessation is associated with low income. Economic reasons are regularly named as a reason for giving up driving (Choi, Mezuk, & Rebok, 2012; Marottoli et al., 1993).

On the other hand, a study also found that people who already gave up driving resumed doing so "…due to the lack of transportation, feelings of insecurity and fear for their survival, and the desire to assist friends who were less fortunate." (Johnson, 2008, p. 65). This again highlights the need to provide alternative means of transportation.

Such alternatives do not necessarily have to be public transport but can also be transportation support from friends and family. However, it is important to make a clear distinction between family and friends. In a study with female drivers who gave up driving in old age, Bauer, Rottunda, and Adler (2003) found two important things:

- "Adaptation came easiest to those who planned ahead for driving cessation and made the decision voluntarily" (Bauer et al., 2003, p. 3009).
- Surprisingly, "family is not the preferred choice for transportation except in an emergency or for basic care" (Bauer et al., 2003, p. 3009).

The latter was also found by Choi, Adams, and Kahana (2012): the availability of transportation support from friends and neighbours was associated with driving cessation, family support was not. The authors conclude that the availability of non-kin alternatives plays a major role in the decision to stop driving.

Although the elderly do not themselves see transportation by their family as their preferred mode of travel, driving cessation is indeed a worrying factor not only for the elderly but also for their adult children (Rosenbloom, 2010). Rosenbloom (2010) points out that alternative measures are expensive but necessary. With the majority of the population being directly (the elderly themselves) or indirectly (their adult children and other family members) affected, such measures must be taken now.

11 Screening and assessment

For older people, giving up driving is a turning point in their lives and they feel like losing an important part of their mobility (Mollenkopf & Engeln, 2008). Giving up driving is related to a further decline in health (Freeman et al., 2006; Marottoli et al., 2000). A better way to give up driving is voluntarily (Musselwhite, 2011). Alternatively, car driving can continue but with age-based restrictions as described by Nasvadi and Wister (2009).

At present, the regulations regarding driver licence validity and how renewal is conducted differ vastly between different European countries. An overview of the different regulations in Europe can be found in the OECD publication on older drivers (OECD, 2001a), in Kienitz, Stamm, and Heusinger von Waldegg (2006), the journal of the European Community (European Commission, 2002) and in Mitchell (2008). Although these listings are not up-to-date there have been few changes since then and there are still considerable differences between the different member states. Differences in Europe extend to (Kienitz et al., 2006):

- the age-limit
- the instruments used for screening
- the qualification of the persons conducting the screening.

In Europe, only Germany, Belgium, Austria and France have licenses without an expiry date (Kubitzki & Janitzek, 2009). However, even if validity is restricted, regulations often only extend to physical and physiological factors which do not reflect the complexity of the issues (Kienitz et al., 2006).

In the United States, generally speaking, licences must be renewed. However, the details vary similarly to Europe. An overview of licensing renewal provisions in the different USA states can be found on the website of the Insurance Institute for Highway Safety (Insurance Institute for Highway Safety (IIHS), 2013). On average, a licence must be renewed every five years (Ewert, 2008).

Against the background of demographic change and varying regulations in Europe, the European Union has demanded a uniform and legally binding renewal of driving licenses from the age of 65.

However, calendar age alone is an insufficient predictor of traffic safety (see previous chapters). It is assumed that motor, sensory and cognitive changes are responsible for the increased accident risk of older drivers aged 75 years and older (Pottgießer, 2012; Schlag, 2008a).

Although correlations were found between singular aspects of capability and traffic safety (Ball et al., 2006; Lee, Lee, Cameron, & Li-Tsang, 2003; Oswanski et al., 2007) this relationship is usually weak and only valid with great uncertainty. It is thus not surprising that up to now it has not been possible to prove the positive effect of screenings on traffic safety (Bohensky, Charlton, Odell, & Keeffe, 2008; Dobbs, 2008; Hakamies-Blomqvist, Johansson, & Lundberg, 1996; Langford, Fitzharris, Newstead, & Koppel, 2004; OECD, 2001a; Ross, Browning, Luszcz, Mitchell, & Anstey, 2011), for the few exceptions, see Loughran et al. (2007).

The risk of using screening measures is that they usually do not work with enough sensitivity and specificity. An example of the implication of insufficient sensitivity and specificity is given in Figure 79 and Figure 80. The discussion of any screening must be based on an assessment of the benefits and costs of the outcomes and the reliability and validity of the tests and measures on which this outcome is based. Regarding the general outcome, the potential results can be arranged in a four-field matrix as shown in Figure 79.

The numbers shown in the table of confusion in Figure 80 result from a fictitious example with the subsequent specifications:

- General population of interest: 2,000,000
- Prevalence of being unfit to drive in the population [%]: 5
- Sensitivity of the test [%]: 99
- Specificity of the test [%]: 99

Despite the unusually high specificity and sensitivity of the fictitious test, this would result in nineteen thousand false positive cases. These would be drivers whose license would be taken despite the fact they would actually be capable of driving.

It is not surprising that both the OECD (2001a) and the European Federation of Psychologists' Association (EFPA) (Meng, 2010) oppose mandatory screening of older drivers (see also Meng, 2011; Siren & Meng, 2012).

An alternative to mandatory age-based testing or screening could be the support of health professionals. It has been shown that older people are more likely to give up driving when they were advised to by their GP (general practitioner) (D'Ambrosio et al., 2009). On the other hand, studies also have shown that medical doctors are reluctant to give this advice because they do not feel qualified to do so (Jang et al., 2007). Based on such findings, Eby and Molnar conducted an expert panel on driver licensing policy. The experts gave the following advice regarding health professionals (Molnar & Eby, 2008, cited in Eby & Molnar, 2009, p. 292):

		Capable to drive in reality?	
		No (A gold standard test would be POSITIVE)	**Yes** (A gold standard test would be NEGATIVE)
Test result?	**Positive** (Meaning: NOT capable to drive)	**True Positive (TP)** Sensitivity = TP/(TP+FN)	**False Positives (FP)**
	Negative (Meaning: Capable to drive)	**False Negatives (FN)**	**True Negative (TN)** Specificity = TN/(FP+TN)

Figure 79: Matrix visualizing potential outcomes of test results in relation to actual capability (source: TU Dresden, based on own calculation).

		Capable to drive in reality?	
		No (A gold standard test would be POSITIVE)	**Yes** (A gold standard test would be NEGATIVE)
Test result?	**Positive** (Meaning: NOT capable to drive)	**9,9000**	**19,000**
	Negative (Meaning: Capable to drive)	**1,000**	**1,881,000**
		10,000	**1,900,000**

Figure 80: Table of confusion depicting the resulting numbers of a fictitious test example (source: TU Dresden, based on own calculation).

- “Develop standardized 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 specialized driving evaluations.
- Develop education programs 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.
- Develop resources through community collaboration to support the transition from driving to alternative modes of mobility.”

Some additional recommendations were given regarding further research as part of this expert discussion (Molnar & Eby, 2008, cited in Eby & Molnar, 2009, p. 291):

- Design and test screening and assessment tools and/or programs 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 cut-offs and addressing sensitivity and specificity trade-offs).
- 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.
- To determine effectiveness, expand evaluation of programs/practices to promote older driver safety and mobility.

12 Provide alternatives to driving: Preserving the mobility of older people who quit driving

In general, mobility, health, and well-being are closely correlated. Driving a car is positively associated with life quality, functional independence, and physical and mental health and its cessation with a decline in these variables (Li et al., 2003; Marottoli et al., 2000). Driving helps to delay the physical and mental decline associated with ageing because it makes it easier to maintain social contacts and activities of daily living (Berry, 2011). There is also evidence that the loss of mobility is connected with depression (Fonda et al., 2001; Ragland, Satariano, & MacLeod, 2005). Freeman et al. (2006) showed that the risk for the elderly of being in long-lasting care is five times higher for people who stopped driving a car for more than 6 months. Thus, preserving the mobility of the elderly who quit driving must be seen as an aim with highest priority.

Windsor and Anstey (2006) who applied the Social Cognitive Theory of Bandura (2005) in the context of driving cessation of the elderly identified three aspects which must be met by alternative means of transportation

- feeling of self-efficacy,
- feeling of self-regulation, and the
- feeling of exertion of control over the environment.

The alternatives to driving (public transport, cycling, going by foot or using public or private individual transport, i.e. taxis and being driven by relatives and friends) fulfil these aspects to different degrees. Although this report primarily deals with driving, some general considerations regarding this topic will be given.

In addition to available means of transportation, the elderly often require additional programs that fulfill their needs. Two USA publications describe such programs and give advice for their implementation: a report by the United States Government Accountability Office (GAO) (2004) and a report by the Beverly Foundation (2004). Some of the key factors from these reports are summarized below.

The United States Government Accountability Office stated in their report (GAO, 2004) that it is necessary for governmental bodies to provide alternatives to driving. Unless they do so, "… seniors may perceive that driving is their only option and may become isolated or drive even when it is unsafe for them to do so." (GAO, 2004, p. 6).

The public programs mentioned in the GAO report (2004) include programs which provide assisting in purchasing vans, the reimbursement of taxi or other transportation costs and the provision of transport.

These programs are specifically designed to support older citizens who gave up driving and who additionally cannot make full use of public transport. Supplemental Transportation Programs (STP) are thus usually designed for the “old old”, often from the age of 85+. Table 11 gives some key data of STP in the United States of America. Although there will likely be vast differences in the funding between the USA and Europe, the table gives a good overview of the services offered.

The Beverly Foundation (2004) defined senior-friendly transportation along the five A’s:

- Availability: Transportation exists and is available when needed (e.g., transportation is at hand, evenings and/or weekends).
- Accessibility: Transportation can be reached and used (e.g., bus stairs can be negotiated; seats are high enough; bus stop is reachable).
- Acceptability: Standards are upheld in conditions such as cleanliness (e.g., the bus is not dirty); safety (e.g., bus stops are in safe areas); and user-friendliness (e.g., transit operators are courteous and helpful).
- Affordability: Fees are affordable; fees are comparable to or less than driving a car; vouchers or coupons help defray out-of-pocket expenses.

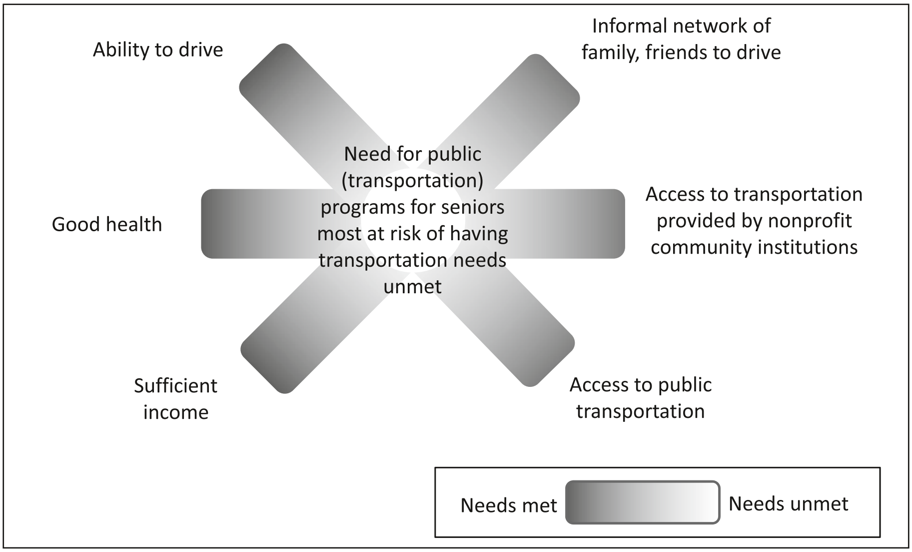

Figure 81: Diagram of the overlapping factors affecting seniors’ mobility needs (source: GAO, 2004, p. 6).

- Adaptability: Transportation can be modified or adjusted to meet special needs (e.g., wheelchair can be accommodated; trip chaining is possible).

Table 11: Key data of Supplemental Transportation Programs for Seniors who stopped driving (source: The Beverly Foundation, 2004, p. 10)

Location	40 % target rural areas; 21 % urban; 13 % suburban; 28 % mixed
Longevity	50 % established since the mid 1980s
Organization	80 % non-profit
Purpose	61 % medical; 42 % social; 19 % religious; 35 % any purpose
Availability	58 % daytime; 50 % weekdays
Service	71 % door-to-door service; 19 % curb-to-curb; 10 % fixed route
Escorts	47 % provide or can provide escort services
Vehicles	50 % use vans; 42 % use autos; 29 % use buses; 6 % use taxis
Rider fees	57 % no fees; 21 % flat rate fee; 11 % mileage rate; 8 % sliding fee
Drivers	34 % volunteers only; 42 % paid only; 20 % mix of both
Funding	63 % grants; 51 % fees or donations from riders; 18 % tax revenue
Problems	41 % finances; 40 % insurance; 36 % driver issues

Similar important aspects for the use of public transportation by elderly citizens were also found in the German project “ANBINDUNG” (Engeln & Schlag, 2001). These five A`s were also the basis along which a recent British resource guide for local authorities grouped available UK programs (DfT, 2012).

For those seniors who cannot use public transport being driven by relatives or friends might be the only option to sustain their mobility. This situation is particularly unsatisfying for the elderly because the aspects defined by Bandura (2005) (see above) are not met.

Windsor and Anstey (2006) summarized some measures and programs that were designed to assist elderly and relatives in this situation. The key concept behind these programs is to ease communication:

“Communication of the needs and expectations of both older adults with mobility restrictions, and those in a position to assist with transportation is needed in order to strike an effective balance between adequate mobility, and any real or perceived imposition on family members.” (Windsor & Anstey, 2006, p. 210).

Summarizing this chapter it is obvious that mobility, health and well-being are closely related. Since remaining mobile becomes more and more difficult with increasing age all stakeholders must work together to support the elderly.

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Every human being has a basic need for mobility. Whereas mobility demands can be a burden to many of today's young working people, it has a predominantly positive connotation in the everyday life of older people. Mobility makes it possible to meet individual needs, to participate in an active social life, and it is an important prerequisite for independence. However, it is paradoxically in old age that both the type and the scope of mobility become restricted. This restriction is a result of declining sensory, motor and cognitive abilities.

Of all the different forms of mobility, car driving and its risks are of particular interest in our society. Car accidents often not only affect the person causing the accident but also second parties. In addition, the media relishes reporting dramatic accidents where older people are at fault. This influences the perception of the risk associated with older drivers. However, car-driving is the most loved means of transportation for current and future generations of our aging population.

This volume discusses the actual risk of driving in old age. Furthermore, approaches and alternatives for age-friendly auto-mobility are discussed and their implementation is briefly outlined. These are illustrated using examples from selected European cities and communities.

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