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The proportion of senior citizens (aged 65+) will grow from about 15% in the year 2000 to about 30% in the year 2050. The share of older drivers in the driver population will grow even faster because of increasing licensing rates among the ageing population. Older drivers do not have higher accident risk than others. They do however have higher risk of being injured and killed in accidents because of their with age increasing physical frailty.

Generally speaking, safety measures targeted towards older driver are beneficial for all. In the present report measures are described that focus on the drivers, on the traffic environment, on vehicles and on ITS applications.

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Äldrepopulationen (65+) kommer att växa från ca 15 % år 2000 till ca 30 % år 2050. Äldre förares andel i förarpopulationen kommer att växa ännu mera på grund av att allt fler äldre kommer att ha körkort. Äldre förare som grupp har inte högre olycksrisk än andra. Däremot skadas och dödas de lättare då en olycka inträffar på grund av sin med åldern ökande fysiska skörhet.

Generellt sett är trafiksäkerhetsåtgärder som planeras med hänsyn till äldres behov bra för alla. I rapporten beskrivs åtgärder som fokuserar på föraren själv, trafikmiljön, fordonet och ITS-tillämpningar.

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Preface

The present VTI report is a review on older drivers with focus on safety. It is the result of a collaborative effort between researchers at the Swedish National Road and Transport Research Institute (VTI), at the University of Helsinki (UH), Finland, and at SWOV Institute for Road Safety Research (SWOV), the Netherlands.

This report was written by the following persons: Liisa Hakamies-Blomqvist at VTI, Anu Sirén at UH, and Ragnhild Davidse at SWOV (mainly for chapters on infrastructure and ITS). We also wish to acknowledge the valuable support given by Desmond O'Neill who contributed to chapter 2 (on ageing) and Gabriel Helmers, VTI, and Per Henriksson, VTI, who contributed to chapter 4 (on infra-structure).

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Linköping, March 2004

Liisa Hakamies-Blomqvist

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Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ACC	Adaptive Cruise Control
AGILE	AGed people Integration, mobility, safety and quality of Life Enhancement through driving
DAT	Dementia of Alzheimer Type
EDDIT	Elderly and Disabled Drivers Information Telematics
FARS	Fatality Analysis Reporting System
GADGET	Guarding Automobile Drivers through Guidance Education and Technology
ICC	Intelligent Cruise Control
ISIS	In-vehicle Signing Information Systems
ITS	Intelligent Transport Systems
LCCW	Lane-Change Collision Warning system
LCCWA	Lane-Change Collision Warning and Avoidance system
MUTCD	Manual on Uniform Traffic Control Devices
UFOV	Useful Field of View
VES	Vision Enhancement System

Older drivers – a review

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Executive Summary

The aim of the present report is to provide a review of older drivers, with special emphasis on older drivers´ needs for safety and mobility. The report focuses on issues of older driver population heterogeneity, infrastructure developments, and on the older old drivers (aged 75+). An effort is also made to forecast some expected changes in the transportation system and in the population of older drivers.

History of older driver research

The “older driver problem” first became established as a result of research activities by the end of the sixties, mainly in the U.S. As a result of these efforts general trends in accident rates and exposure characteristics were found. The importance of different aspects of vision for safe driving was also thoroughly studied.

Summarising the findings in 1972, the deficiencies of the ageing driver seemed to fall into two overlapping categories: those due to the ageing process itself and those due to some medical disability. First, in harmony with the concurrent interest in accident proneness the driver’s “deficiencies” were seen exclusively as the cause of all problems, and the characteristics of the traffic system were taken largely for granted. The general recommendations were dominantly oriented towards screening drivers and eliminating those with higher risk from the driver population.

Once it had been settled that there was an “older driver problem”, research in the eighties was directed toward a more thorough understanding of the general traits of this problem. Thus, it was shown that older drivers are "good insurance risks" but have more accidents per distance driven. When involved in an accident, older drivers were found to be more often the party at fault. Older drivers were shown to be overrepresented in accidents occurring at intersections and in other complex traffic situations. On the other hand, they turned out to have less single-vehicle accidents. It also was settled that the accidents of older drivers mostly occurred in daytime and that accident-involved older drivers were less often alcohol-intoxicated than accident involved young or middle-aged drivers.

Attempts to explain the emerging accident picture of older drivers were mostly based on an ad hoc model of thinking based on three elements of knowledge: (1) a task analysis of car driving, (2) gerontological data about age-related changes in different aspects of human performance, and (3) accident statistics. From these three elements of knowledge, hypothetical explanations were generated by matching the information about which faculties are necessary for safe driving. Since (1) vision certainly is one of the necessary faculties for safe driving, and (2)

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several visual functions deteriorate with age, and (3) older drivers were overrepresented in intersection accidents where they failed to see their collision partners in time. So, age-related changes in vision often were blamed for these accidents.

But this model of thinking failed to take into account the nature of driving as a skilled performance with a long learning history. To regard driving as skilled performance has become increasingly popular since the beginning of the nineties. This approach certainly shows promise toward a deeper understanding of the weaknesses, strengths, and compensatory strategies of older drivers.

One of the corner stones of the redefinition of the older driver problem, the claim concerning their higher accident rates, was contested in the eighties when it was pointed out that a higher risk of injury leads to sampling bias in accident data bases. As demonstrated by Evans (1991), the greater physical frailty of older individuals explains an important part of their higher rates of injury and fatal accidents. Challenging the traditional problem definition, Evans concluded that for older drivers, accident risk in fact was a minor issue, and limitations in mobility, due to self-imposed compensatory restrictions in driving exposure, were the real problem.

An important turn in the research appeared in the late 1980's, shifting focus from a general approach toward a differential one. Research had long since shown that interindividual variance in most performance variables increases with age. Clinical experience pointed out certain subgroups of older patients having illnesses that could affect abilities essential for safe driving as a major source of safety concern, rather than persons suffering from nothing more than "normal ageing". Thus, while earlier research mostly was guided by the question "Why do older drivers have higher accident risk?" the alternative question "Which older drivers have higher accident risk?" gained momentum. Since then, an important body of research has been produced on different aspects of age-related illnesses and driving.

During the last few years, the area of ageing and transportation has gained in importance. There has also been an important shift of orientation. Earlier, the question of ageing and transportation was mostly articulated in terms of safety alone. Lately, the issue of mobility become a primary concern, with safety regarded as one of its quality dimensions. This change of focus is well exemplified by the two latest OECD reports on ageing and transportation. The earlier one, from 1985, was entitled *Safety of older road users in traffic* and had rather a narrow scope, whereas the one from 2001 is called *Ageing and transportation: Mobility needs and safety issues*, and has a clear ambition to set things in a wider perspective.

Who are the older drivers of today and tomorrow?

It has been projected that in the future the older driver population will increasingly consist of drivers aged 75+, of women drivers, and of active drivers with greater annual mileage. There is increasing interest to focus research especially on the oldest old (80+) drivers and on older women drivers.

The definition of old age in terms of chronological age has changed within the last decades: the boundary mark dividing adulthood from old adulthood has changed from 55–65 years to 75–80 years. In addition, late adulthood often is divided into "third" and "fourth" age, where the third age refers to the active, independent and healthy period of life after retirement, and the fourth age to the last period of life with developed disabilities and increasing dependency on other people. Similarly, in traffic research, the focus of studies on older drivers has shifted from those aged 65+ to those aged 70+ or 75+. Age-related changes affecting driving usually do not become marked before the age of 75. Findings show that in later cohorts the elderly-typical accident patterns appear at later ages than in the earlier cohorts.

Travel patterns and their consequences

Travelling and trip rates decrease with age. Retirement decreases the everyday travel considerably as the number of work-related trips is reduced. In general, the older age group, the less the amount of travel. Compared to other age groups, persons aged 75 and above drive less and use other modes of transportation more. The proportion of older persons driving has however increased during the last decades, and a further increase is predicted. In Sweden, between years 1990 and 2002, the proportion of those holding a driver license in age group 80+ increased from 58.3% to 83.6% among men and from 9.6% to 32.5% among women.

There is a distinctive gender difference in travel of all age groups, with women travelling less than men. Also, in the population aged 75 and above women travel less than men and also hold fewer driver licenses than men do. The older the age group, the more unlikely it is that women hold a driver license. This difference is more marked in European countries than in the USA. This gender difference in driving might however be cohort-related and will probably disappear as new generations reach older age.

Part of the age-related decrease in travel does not necessarily reflect decreased level of personal mobility needs. However, a Finnish study found that older persons, especially those aged 75 and above, and especially women, often wished to do more of everyday trips if it was practically feasible. In this study, personal mobility was strongly related to the option to drive.

Driving does not only seem to be closely related to maintaining satisfactory level of personal mobility, but also to safety and security. Compared to other modes of travel, car driving is a safe travel mode for older persons. When compared to their share of the population, older persons are overrepresented in casualties when using public transportation, and as pedestrians. In Western Europe, older pedestrians account for 45% of the pedestrian fatalities while representing only 15% of the population.

Driving habits

Compared to younger drivers, older drivers in general drive less and with lower average speeds. In both accident analyses and driving behaviour surveys, older drivers are more likely to modify their driving by avoiding difficult driving conditions like rush hours, darkness, bad road-surface conditions, etc. This elderly-typical change of exposure is more pronounced after the age of 75.

Older drivers have been found to experience a markedly increasing amount of problems in various traffic situations after the age of 75, including left turns, signalized intersections, and stop sign intersections. When assessing themselves as drivers, older drivers as a group think of themselves as cautious, courteous, and good drivers as compared to younger ones. Older drivers in general have been found to have less illusory self-assessments than younger drivers. This implies a good level of self-evaluation skills in the elderly. Recent studies have also found that experienced difficulty in driving is related to voluntary reduction and cessation of driving.

In North America a greater dependency on the car is reflected on driving cessation with higher driver ages at the time of cessation. The proportion of persons in the US limiting or stopping their driving starts to increase distinctively from the age of 70 years. However, an earlier study reported a mean age of 85.5 years for driving cessation. In Europe, the rates for licensed drivers among the older persons are markedly lower. But, according to the latest Swedish license holding rates 84% of men and 33% of women aged 80+ hold a driver license. So, the situation in Sweden resembles that of the US.

Women tend to give up their licenses at a younger age than men and more often voluntarily. In general, women are also in better health than men when they give up driving. For men, the main reason to give up driving is health. The health conditions most often found to be related to driving cessation are heart problems, neurological diseases, cognitive impairment, and eye problems. It was found in a study on very old drivers (84+) that these drivers had very few limitations on their daily activities and were not cognitively impaired. Men are also more likely than women to continue driving in spite of increasing health problems. The reasons why older women are more likely to retire from the wheel probably reflects their past driving career. Women have been subjected to more conservative views on gender roles regarding driving and have gained less driving experience than men. Driving probably is more important to male identity. How this gender differences in driving habits will develop in the future remains to be seen but some increase in older women's driving is to be expected.

Social factors also play a part in the decision to stop driving. Married persons and those living in smaller households are more likely to continue driving. Driving cessation is likely to reduce mobility and will have a negative influence on the quality of life.

To understand the consequences of driving limitation and cessation for older road users, driving safety has to be compared with alternative modes of transportation. There is overwhelming evidence that driving is safe compared to other modes of transport. To give up driving often entails a switch to walking, biking and use of public transportation as the primary modes of mobility. Walking and biking, however, are less safe modes of travel for older persons. In most countries, older persons are overrepresented among pedestrian fatalities. Public transportation in itself is safe but leads inevitable to an increased exposure as a pedestrian.

Premature driving cessation is a problem especially for women. Older women who give up their driving at younger age risk exchanging the relative safety of driving a car with the larger risk of being an unprotected road user. Driving cessation limits mobility, increases dependency on other people, and has a detrimental effect on general well-being. So, the negative consequences of driving cessation should be counteracted by stimulating especially older women to continue driving.

The risk of meeting with an accident

In traffic safety forecasts, reference has often been made to older drivers' "over-representation" or "higher risk". Accident statistics seems to show that there is a sharp age-related risk increase of accidents per mileage. Hence, one might conclude that older drivers become more dangerous with age. But this explanation is not correct. In most accident data, cases are included on the basis of the consequences of the accident (such as "leading to personal injury"; "leading to fatality"). For older drivers, this leads to a sampling bias called the “frailty bias”: A larger share of older drivers’ accidents is therefore included in the official statistics because an old person is more easily injured by a given physical impact. This sampling bias makes the age-related risk increase for old persons according to the accident statistics larger than it really is.

It is important to notice that the relationship between yearly mileage and the number of accidents per mile is not linear. Those who have large yearly mileages always have fewer crashes per mile than those who have shorter yearly mileages. This has been found independently of age. Therefore, a fair comparison of any driver group risk of accident per distance travelled should be made in groups matched for yearly mileage.

In a recent study, drivers aged 65 and more were compared against a young middle age group of 26 to 40 years. Overall, the usual finding emerged: older drivers had somewhat more accidents per mile than younger ones. However, when both age groups were divided in subgroups based on annual mileage, and the age comparison was made in groups matched for this variable, all the disadvantage of age disappeared. If anything, the older drivers were safer!

Contrary to a common misconception, older drivers do not present an increased risk to other road users. They are mostly likely to be injured themselves in their accidents, both because of their greater physical frailty and because of the typical accident patterns.

Compared to younger drivers, a larger share of older drivers´ accidents are collisions between vehicles, as opposed to single-vehicle accidents. Older drivers also tend in a higher degree to be the legally responsible party in their collisions. The typical situation is one where the older driver turns left against the oncoming traffic of the main road and is hit by a vehicle having right-of-way. They apparently do not notice the counterpart in time, and fail to give right-of-way. On the other hand, old drivers small share of accidents as non-responsible parties also reflects the fact that they have a slow, conservative and cautious driving style, which makes them “harder to hit” as innocent parties than younger, less defensive drivers.

For older drivers, the increase of intersection accidents has been such a salient finding that less attention is paid to the fact that older drivers are “underrepresented” in other types of accidents, such as single-vehicle accidents involving loss of control, or collisions due to speeding or risky overtaking. The decrease of accidents due to high speeds corresponds well to the changes in the driving habits of older drivers. The large share of accidents in intersections is often interpreted as a sign of older drivers’ failing capacity of dealing with complex environments. Less often is their small share of off-the-road accidents seen as a sign of a mature, safety-oriented driving style.

Why are older drivers not equally successful in avoiding accidents in complex environments such as intersections? Older drivers’ main strategy in facilitating the driving task is to drive more slowly. But negotiating intersections is in many cases not a self-paced task but a forced-paced one. The difficulty is set by intersection design as well as the speeds of the fellow road users. Therefore, older drivers may be forced to perform under time pressure that exceeds their capacity.

In summary: There is no increase in the risk of older drivers as a group to meet with an accident as compared to middle-aged drivers. Older drivers do not increase the risks of their fellow road users. On the other hand when older drivers are hit by an accident their risk of being seriously hurt or killed is considerably larger due to their larger fragility.

Ageing and transportation as a public health issue

Ageing and transportation, viewed as a public health issue, have two main dimensions: safety and mobility. Problems with both lead to adverse consequences for health and societal costs. In the past however, focus has largely been on safety. This is natural because accidents are relatively straightforward events with evident costs for the individual as well as for society. In contrast, the relationship between mobility limitations and loss of health is not equally evident. Briefly: it is necessary for an older person to live an active life and keep his or her former activity patterns; active elders are, statistically speaking, healthier elders than passive ones; health is directly related to functional capacity, and elders with good functional capacity are more able to live autonomous lives and have smaller need for public support, which ultimately leads to savings of public funds. However, an overall analysis of the economic impact of good outdoor mobility for ageing citizens still needs to be done for guiding policymakers' efforts towards good policies regarding ageing and transportation.

Different dimensions of ageing

Ageing is a complex process, bringing at all ages a combination of growth and loss. The positive aspects of ageing are under-appreciated, although the added-value of the older worker is increasingly recognised. The beneficial aspects of ageing include wisdom, strategic thinking and less risk-taking. A striking proof of this is that the older population, despite the highest prevalence of disabilities, have the lowest crash rate per driver of any age group.

A significant feature of ageing is the emergence of increased inter-individual variability. So, generalisations about an individual's performance primarily based on age become increasingly doubtful.

With increasing age, social roles usually change or are in transition; e.g. from parent to grandparent, from employee to retiree, and from married person to a widower. As the personal roles change, the relationship to one's social context also changes which in turn may trigger changes in attitudes and values. These social changes in later adulthood have direct effects on travel behaviour and needs.

Driving as skilled performance

Driving has traditionally been regarded as a complex information processing task. More recently, the understanding of the driving task has deepened. First, driving has increasingly been understood as a process that requires, involves and depends on cognitive processes that include goal setting, planning and other higher behavioural patterns. Second, as driving is understood as a complex skilled performance, it becomes evident that the number of factors contributing to its successful execution is very large. Since these factors are not only physiological or cognitive in nature, but also psycho-social and social, the preconditions for safe driving are not easy to define in a comprehensive manner. In the case of older drivers, the importance of compensation strategies has useful implications to older driver training and assessment as well as to vehicle and road design.

The consequences of the comprehension of the driving task as a complex everyday skilled performance are important. The new understanding of the nature of driving has implications for driver assessment, driver training, as well as for infrastructure design.

Functional age-related changes and the driving task

Here we will briefly go through the physical age-related functional changes that are considered most important for the ability to drive.

Visual function in a driving context usually refers to visual acuity, vulnerability to glare, and contrast sensitivity. Visual acuity can be improved by increasing illumination, and thus improving the lightning conditions on the road could solve some of the problems that older drivers may experience. It is, however, unlikely that this would work as a traffic safety measure, since visual acuity has not been found to be related to accidents. It might however be successful in terms of mobility, as a measure for promoting more comfortable driving for older drivers.

Opacity of the lens can increase the risk of glare. Problems of glare are related to poor illumination and poor reflection qualities of the road. Age-related decrease in contrast sensitivity can cause problems for older driver to read traffic signs. Symbolic signs (in contrast to those with text) are preferable.

Attention is highly relevant for the issue of ageing and driving. The driving task requires division of attention between several sub-tasks, especially in more complex traffic situations like intersections. Older persons have been found to have more difficulties in filtering out irrelevant stimuli. Findings related to attention and ageing might partly explain the problems older drivers experience in intersections and other complex traffic situations. Reaction time and motor performance in general slows down with age. Reaction times to simple stimuli do not deteriorate dramatically but in making decisions in complex situations.

Most common age-related illnesses include arthritis, heart diseases, arterial hypertension, and diabetes. Heart diseases pose certain risks for traffic safety. They have however been found to affect driving habits: after hospitalisation for heart disease driving tends to decrease and eventually mobility is reduced. Diabetes and driving has been largely studied. Recent research suggests however, that patients with diabetes do not have elevated risk for traffic accidents unless the disease is severe.

Dementias cause impairments in cognitive abilities and judgement skills that can manifest themselves as difficulties in driving. Dementias are degenerative diseases, but depending on the type of dementia, the effects on driving ability can take 1–10 years to become apparent. Cognitive impairment and dementia are associated with driving difficulty, driving reduction, and driving cessation. Dementias at more progressed stages will eventually impair the ability to operate the car. The impact of demented drivers on traffic safety on a general level is difficult to estimate. The estimation of the accident risk itself is hard to establish empirically. But, the fact that dementia and related impairments tend to lead to a reduction of driving exposure suggests that the overall exposure of impaired drivers is minor – thus creating a very modest problem for traffic safety in general.

Safety measures targeted to older drivers – Restrictive policies

The most commonly discussed safety measure related to older drivers has been the restriction of driving, mainly by identifying and excluding from the wheel those who are "too risky" to drive. But, how shall we know which drivers are "too risky"? Given the complex nature of the driving skill, deficits in almost any single function can be compensated for by adjustment of performance.

As a basis for exclusion from traffic, we need indices that are predictive for safety. We have no ethical or scientific grounds to exclude from driving except for those who have a higher risk of accident. Hence, any diagnostic criterion for exclusion should ultimately be validated against accidents. This is however difficult to achieve, because accidents are, on the individual level, rare events.

Age-related screening is often suggested as an effective safety measure. But the measure is based on the erroneous idea of older drivers as a high-risk group. The general idea would be to regularly "check" license holders after a certain age in order to exclude from the driver population those with increased accident risk. This idea is jumping up again and again, it has false face validity, and it opens up for wonderful business opportunities. However, all serious studies that have aimed to evaluate the safety effects of general age-based driver screening have failed to show any benefits (for an overview, see OECD, 2001).

Safety measures targeted to older drivers – Supportive actions

As the importance of independent mobility for older persons has been recognised, an increasing number of safety measures of more supportive nature have emerged. These include older driver training and re-training, and rehabilitation of drivers whose driving ability has decreased due to some health-related deficits. The increase in different older driver training courses and educational resources reflects the growing understanding of differents aspects of driving, such as the positive impact of compensatory strategies in driving. These courses and programmes are usually rather young, established in the 1990's, and there are no published systematic evaluations.

Safety measures targeted to older drivers – Road design

Older drivers do not dramatically differ from middle-aged drivers in their driving performance. But older drivers as a group have larger problems especially in complex traffic situations as compared to younger groups of experienced drivers. There are several measures that affect positively the premises for safe and comfortable driving for older drivers by means of road design. These measures are usually advantageous for all drivers regardless of age. Here, we shall focus on the importance of road design in more general terms by presenting some general principles. For information about specific road design elements that are most favourable for older drivers we refer to section "Road design" in the report.

General principles for road design

Some general principles based on empirical knowledge and reliable experiences can be formulated. These principles apply to all road users but have special importance for seniors.

1) Roads should be built according to standards reflecting their function so that the expectations of the road user about how the road will continue and how the fellow road users will behave are verified.
2) The road should contain as much redundant information as possible. In other words, all elements of the road and the road environment should interact to give an unmistakable and clear message about the function of the road.
3) A correctly designed road will both create correct expectations of the driver and support effective information processing by creating good preconditions for automatization of driver behaviour.
4) The road should be designed so that the driver is allowed enough time to perform one demanding task at a time.
5) Intersections should be built so that the drivers can without difficulty understand the layout of the intersection. The drivers should also have clear and continuous information of where in the intersection they are while driving through it.
6) Roads should be built so that the mental load of the driver is neither too low nor too high; normally, the load should be decreased in intersections and increased between them.
7) Road signs should be placed in locations where the drivers need the information, where the drivers can interpret the information (in relation to the road) and where the drivers have the time to read the signs.
8) To navigate is a strategic problem-solving task. Therefore, navigating information should be logical, consequent and hierarchical in nature.
9) Information supporting tactical decisions should be evident and conspicuous at sufficient distances. Similarly, road markings and other elements supporting operational decisions should be visible early enough for adaptive manoeuvres.

Safety measures targeted to older drivers – Vehicle design

Many of the age-related physical changes and deficits do not affect the observed quality of driving performance but can affect the subjective experience of driving. However, the comfort of driving can be helped with proper design. Better design to ease the older person’s entry and exit of the car has been suggested. More adjustable in-vehicle equipment can enable the driver to concentrate more on the driving task itself.

Another type of design is to protect the driver and passengers – passive safety. This includes restraint systems like seatbelts and airbags, improved vehicle crashworthiness, and better structural performance of the vehicle. Older drivers especially gain from these design improvements, but the special qualities and needs of the older population should be taken into the further design processes.

Intelligent Transport Systems (ITS) encompass a broad range of communications-based information, control and electronic technologies in cars. The development of these technologies started in the 1980’s. There has since then been a strong hope that this technology would be introduced on the market in different applications in a few years time in order to improve safety as well as capacity on the road considerably. Yet, these expectations have not been fulfilled. In the light of the minor progress that is seen up to now the expectations have been over-optimistic. So, we are still waiting for god driver aids on the marketplace based on ITS technology.

One important demand of the ITS equipment to come is that it must not add any extra burden to the driving task in order to ease driving of older drivers. In fact, the development of ITS applications and prototypes has to a high degree been technology driven as opposed to driver centred. Therefore, it seems unlikely that the first generations of ITS equipment on the marketplace will fulfil this demand and ease driving for older drivers.

Conclusions and recommendations

1) The old part of the population (65+) will grow from about 15% in 2000 to about 30% in 2050.
2) Older drivers as a group are driving equally safely as younger experienced drivers.
3) Older drivers do not constitute an increased risk for their fellow road-users.
4) Screening of drivers from a certain age is not an effective measure for increasing traffic safety.
5) When older drivers meet with an accident they have an increased risk of being seriously injured or killed compared to younger age groups. This is due to their greater fragility related to age.
6) Compared to other modes of transportation, driving is safe also for old drivers.
7) Traffic safety should be viewed in a public health perspective in order to balance the legitimate demands of the ageing citizens concerning both mobility and safety.
8) Mobility of the aging citizens by driving can be improved by supporting the continuation of driving especially for old women as well as by improving the design of cars and roads.

Äldre förare – en översikt

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Sammanfattning

Syftet med denna rapport är att ge en översikt över äldre bilförare med särskild tyngdpunkt på äldre förares säkerhets- och mobilitetsbehov. Rapporten fokuserar på frågor som rör den äldre förargruppens heterogenitet, utvecklingen av infrastrukturen och på ”äldre äldre” förare, dvs. 75 år eller äldre. En ansats görs också till att förutse några förväntade förändringar i transportsystemet och i populationen av äldre bilförare.

Forskningen kring äldre bilförare – en historik

”Äldre bilförarproblemet” blev först etablerat som ett forskningsresultat mot slutet av 1960-talet, främst i USA. Som ett resultat av dessa insatser, fann man generella trender i olyckstal och exponeringsdata. Betydelsen av olika synfunktioner för säker bilkörning undersöktes också noggrant.

När resultaten summerades år 1972, föreföll den äldre förarens brister kunna hänföras till två överlappande kategorier: de som berodde på själva åldrandeprocessen och de som berodde på någon medicinsk funktionsnedsättning. Först, i enlighet med det samtida intresset för olycksbenägenhet, sågs förarens “brister” uteslutande som orsaken till alla problem, medan trafiksystemets utformning i stort sett togs för given. De allmänna rekommendationerna var huvudsakligen inriktade på att screena förarna och eliminera dem med högre risk från förargruppen.

Efter att det slagits fast att ett “äldre bilförarproblem” existerade, inriktades forskningen under 1980-talet på att få en djupare förståelse för de generella kännetecknen för detta problem. Sålunda visades det att äldre förare var "goda försäkringsrisker" men var inblandade i fler olyckor per körd sträcka. När äldre förare var inblandade i en olycka, fann man att de oftare var den skyldiga parten. Äldre förare visade sig vara överrepresenterade i korsningsolyckor och i olyckor i andra komplexa trafiksituationer. Å andra sidan var de inblandade i färre singelolyckor. Det fastställdes också att de äldre förarnas olyckor oftast inträffade under dagtid och att olycksdrabbade äldre förare i mindre utsträckning var påverkade av alkohol än unga och medelålders förare.

Försöken att förklara den olycksbild som framträdde för äldre förare utgick vanligen från en ad hoc–tankemodell baserad på tre kunskapsbitar: (1) en analys av bilkörningsuppgiften, (2) gerontologiska data om olika åldersrelaterade förändringar av människans prestationer och (3) olycksstatistik. Utifrån denna kunskap togs hypotetiska förklaringar fram genom att koppla den till vilka förmågor som är nödvändiga för säker bilkörning. Eftersom (1) syn med säkerhet är en av de nödvändiga förmågorna för säker körning, (2) ett flertal synfunktioner försämras med åldern och (3) äldre förare var överrepresenterade i korsningsolyckor där de

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misslyckade med att i tid upptäcka den de kolliderade med, fick synförändringar skulden för att olyckor av denna typ inträffade.

Men denna tankemodell tog inte hänsyn till att bilkörning är en skicklighetsbaserad färdighet med en lång inlärningsperiod. Detta betraktelsesätt har ökat i popularitet sedan början av 1990-talet. Synsättet visar med säkerhet en lovande utveckling mot en djupare förståelse av äldre förares svagheter, styrkor och kompensationsstrategier.

En av hörnstenarna vid omdefinerandet av äldre bilförarproblemet, påståendet att de har högre olycksrisker, bestreds under 1980-talet när det framhölls att en högre skaderisk leder till urvalsbias i olycksdatabaserna, som Evans visade 1991, förklarar äldre personers ökade fysiska skörhet en betydande del av deras högre frekvenser av personskadeolyckor och olyckor med dödlig utgång. Evans drog slutsatsen och utmanade därmed den traditionella problemdefinitionen, att olycksrisker för äldre förare var en fråga av mindre betydelse och att det verkliga problemet i stället utgjordes av begränsningar i mobiliteten som följd av självpåtagna kompensatoriska restriktioner av exponeringen som bilförare.

Mot slutet av 1980-talet inträdde en viktig vändning i forskningen som innebar ett skifte från ett generellt till ett differentiellt synsätt. Forskningen hade sedan lång tid tillbaka visat att för de flesta mått som beskriver prestationer ökar skillnaderna mellan individer med ökande ålder. Klinisk erfarenhet pekade ut vissa delgrupper av äldre patienter med sjukdomar som kunde påverka förmågor som är väsentliga för säker bilkörning som en större säkerhetrisk snarare än personer som endast genomgick ett “normalt åldrande”. Så medan tidigare forskning till större delen styrdes av frågan "Varför har äldre förare en högre olycksrisk?" har den alternativa frågan "Vilka äldre förare har högre olycksrisker?" vunnit terräng. Sedan dess har en betydande mängd forskning tagits fram med olika aspekter på åldersrelaterade sjukdomar och bilkörning.

Under de senaste åren har området åldrande och transporter ökat i betydelse. En viktig ändring av inriktningen har också skett. Tidigare diskuterades frågan om åldrande och transporter oftast enbart i termer av säkerhet. Senare har mobilitetsfrågan blivit en primär angelägenhet och säkerhet ses som en av dess kvalitetsdimensioner. Den här förändringen i synsättet kan exemplifieras med de två senaste OECD-rapporterna om åldrande och transporter. Den tidigare av dem, som gavs ut 1985, hade titeln *Safety of older road users in traffic* och hade ett ganska smalt angreppssätt, medan den från 2001 med titeln *Ageing and transportation: Mobility needs and safety issues* hade en tydlig ambition att ha ett vidare perspektiv på saker och ting.

Vilka är dagens och morgondagens äldre bilförare?

En bild framträder av den framtida äldre bilförargruppen med ett ökande inslag av förare i åldern 75+, av kvinnliga förare och av aktiva bilförare med längre årliga körsträckor. Det finns ett ökande intresse att inrikta forskningen speciellt på de äldsta (80+) förarna och på äldre kvinnliga bilförare.

Definitionen på hög ålder med avseende på kronologisk ålder har förändrats de senaste decennierna: gränsen mellan mogen ålder och ålderdomen har ändrats från 55–65 år till 75–80 år. Dessutom har ålderdomen delats in i den ”tredje” och ”fjärde” åldern där den tredje åldern syftar på den aktiva, oberoende och friska perioden efter pensioneringen och den fjärde åldern på den sista perioden i livet med märkbara funktionsnedsättningar och ett ökat beroende av andra människor.

Inom trafikforskningen har det samtidigt skett en ändrad inriktning mot dem i åldrarna 70+ eller 75+ i stället för 65+. Åldersrelaterade förändringar som påverkar bilkörningen brukar inte bli märkbara före 75 års ålder. Forskningsresultat visar att i senare kohorter uppträder det typiska olycksmönstret för äldre i senare ålder jämfört med tidigare kohorter.

Resvanor och konsekvenserna av dem

Resandet och antalet resor minskar med åldern. Pensioneringen medför en markant nedgång i det dagliga resandet eftersom antalet arbetsrelaterade resor minskar. Generellt gäller att ju äldre gruppen är, desto mindre är resandet. Jämfört med andra åldersgrupper, kör 75-åringar och äldre mer sällan bil och utnyttjar oftare andra ressätt. Andeln äldre personer som kör bil har emellertid ökat under de senaste decennierna och en fortsatt ökning förväntas. I Sverige ökade mellan åren 1990 och 2002 andelen körkortsinnehavare i gruppen 80+ från 58,3 % till 83,6 % bland män och från 9,6 % till 32,5 % bland kvinnor.

Det finns en tydlig könsskillnad beträffande resandet i alla åldersgrupper: kvinnor reser mindre än män. Även i gruppen 75 år och äldre, reser kvinnor mindre och är i mindre utsträckning körkortsinnehavare än män. Ju högre upp i åldrarna, desto mindre sannolikt är det att kvinnor har körkort. Den här skillnaden är tydligare i europeiska länder än i USA. Denna könsskillnad i bilkörning kan emellertid vara kopplad till kohorter och skulle kunna försvinna när nya generationer når hög ålder.

Delar av nedgången i resandet på äldre dagar behöver inte nödvändigtvis reflektera en lägre grad av personliga mobilitetsbehov. Men resultat från en finsk studie visade att äldre personer, särskilt 75+ och kvinnor, ofta önskade genomföra fler vardagliga resor om det var praktiskt möjligt. I den studien var den egna mobiliteten starkt förknippad med möjligheten att köra bil.

Bilkörning tycks inte enbart vara nära förknippat med att bibehålla en tillfredsställande nivå av den egna mobiliteten, utan också med säkerhet och trygghet. I jämförelse med andra transportsätt, är bilkörning ett säkert sätt att förflytta sig för äldre personer. Äldre personer är, i relation till deras andel av befolkningen, överrepresenterade i olycksfall vid resor med allmänna kommunikationsmedel och som gående. I västeuropa svarar äldre fotgängare för 45 % av dödsfallen trots att de utgör endast 15 % av befolkningen.

Körvanor

Jämfört med yngre förare, kör äldre i regel mindre och med lägre hastigheter. I både olycksanalyser och studier av körbeteende visar det sig att äldre förare är mer benägna att förändra sin körning genom att undvika svåra körsituationer som rusningstider, mörker, dåligt väglag etc. Den här typiska förändringen av exponeringen är mer uttalad efter 75 år ålder.

Man har funnit att äldre bilförare får kraftigt ökade svårigheter i olika typer av trafiksituationer efter 75 års ålder, som vid vänstersvängar, i signalreglerade korsningar och i korsningar med stopplikt. När de bedömer sig själva som förare, betraktar äldre sig som en grupp försiktiga, hänsynstagande och bra förare i jämförelse med yngre. Äldre förare har visat sig i allmänhet ha en mindre overklig uppskattning av sig själva än yngre bilförare. Detta medför en god nivå vad gäller förmågan till självbedömningar hos de äldre. Nyligen genomförda studier har också visat att erfarenheter av svårigheter med bilkörning har samband med frivillig begränsning och upphörande av bilkörning.

I Nordamerika återspeglas det större beroendet av bilen i högre åldrar vid tidpunkten för bilkörningens upphörande. Andelen personer i USA som begränsar sin bilkörning eller slutar köra, börjar öka markant från 70 års ålder. I en tidigare rapport nämns emellertid en genomsnittsålder av 85,5 år när man slutar med bilkörning. I Europa är körkortsfrekvenserna bland äldre betydligt lägre. Men enligt den senaste svenska körkortsstatistiken är 84 % av männen och 33 % av kvinnorna i åldern 80+ innehavare av körkort. Sålunda liknar situationen i Sverige den i USA.

Kvinnor tenderar att avstå från bilkörning vid lägre åldrar än män och oftare på frivillig basis. I allmänhet har kvinnorna också bättre hälsa när de beslutar att sluta köra bil. För männen är hälsan huvudorsaken till att upphöra med bilkörning. De hälsotillstånd som oftast har framkommit som relaterade till upphörande av bilkörning är hjärtproblem, neurologiska sjukdomar, kognitiv svikt och ögonproblem. Resultat från en studie av mycket gamla förare (84+) visade att de hade väldigt få begränsningar i sina dagliga aktiviteter och att de inte hade kognitiva nedsättningar. Det var också mer troligt att män fortsatte köra trots ökande hälsoproblem. Anledningarna till att äldre kvinnor är mer benägna att inte längre sitta bakom ratten står troligen att finna i deras tidigare körkarriär. Kvinnor har varit föremål för en mer konservativ syn på könsroller beträffande bilkörning och har förvärvat mindre körerfarenhet än män. Förmodligen betyder bilkörning mer för mannens identitet än för kvinnans. Hur denna könsskillnad i körvanor utvecklas i framtiden återstår att se, men en ökad bilkörning bland äldre kvinnor kan förväntas.

Sociala faktorer spelar också en roll vid beslutet att inte köra bil längre. Det är mer sannolikt att gifta personer och de som tillhör små hushåll fortsätter att köra. Att sluta köra bil innebär antagligen en försämrad mobilitet och påverkar livskvaliteten negativt.

För att förstå konsekvenserna för äldre trafikanter av att begränsa eller avstå från bilkörningen, måste säkerheten vid bilkörning jämföras med alternativa transportmöjligheter. Det finns en överväldigande mängd belägg för att bilkörning är säkert jämfört med andra transportsätt. Att sluta köra är ofta förenat med en övergång till att gå, cykla och utnyttja allmänna kommunikationer som de primära sätten att vara mobil. Att gå och cykla är emellertid mindre säkra sätt att förflytta sig för äldre personer. I de flesta länderna är äldre personer överrepresenterade bland fotgängarolyckor med dödlig utgång. Allmänna kommunikationer är i sig säkra men de leder oundvikligen till en ökad exponering som fotgängare.

Att sluta med bilkörning för tidigt är ett problem särskilt för kvinnor. Äldre kvinnor som slutar köra vid lägre åldrar riskerar att ersätta den relativt säkra bilkörningen med den större risken att vara en oskyddad trafikant. Att ha slutat köra bil begränsar mobiliteten, ökar beroendet av andra personer och har en skadlig inverkan på det allmänna välbefinnandet. Följaktligen bör de negativa konsekvenserna av att sluta köra förhindras genom att stimulera särskilt äldre kvinnor att fortsätta köra bil.

Risken att råka ut för en olycka

I trafiksäkerhetsundersökningar har det ofta hänvisats till äldre förares ”överrepresentation” eller ”högre risker”. Olycksstatistik verkar visa att det finns en kraftig åldersrelaterad ökad risk för olyckor i förhållande till körd sträcka. Därmed skulle slutsatsen att äldre förare blir farligare med stigande ålder kunna dras. Denna förklaring är dock inte riktig. I olycksstatistik är ofta fall medtagna beroende på olyckans konsekvenser (t.ex. ”ledande till kroppsskada”; ”vållande till dödsfall”). För äldre förare leder detta till en bias som kallas ”skörhetsbias”: En större andel av äldre förares olyckor ingår därmed i den officiella statistiken eftersom äldre personer lättare skadas vid sammanstötningar. Denna bias i urvalet medför att den åldersrelaterade ökningen av riskerna för äldre enligt olycksstatistiken blir större än vad den i verkligheten är.

Det är viktigt att ha i åtanke att relationen mellan årlig körsträcka och antalet olyckor per km inte är linjär. De som har lång årlig körsträcka har alltid färre olyckor per km än de som kör mindre. Detta står sig i alla åldersgrupper. Därmed bör jämförelser av olycksrisker i alla förargrupper göras i grupper matchade med avseende på årlig körsträcka.

I en färsk studie jämfördes förare över 65 års ålder med förare i yngre medelåldern, 26–40 år. Generellt konstaterades de förväntade resultaten: äldre förare råkade ut för något fler olyckor per km än yngre. När man delade in förarna i grupper på basis av årlig körsträcka och sedan analyserade åldersskillnaderna försvann dessa. Om något, befanns de äldre förarna vara säkrare!

I motsats till vad många tror, innebär inte äldre förare någon ökad risk för andra vägtrafikanter. De löper störst risk att själva skadas i olyckor, dels pga. deras större skörhet, dels pga. de typiska olycksmönstren.

Jämfört med yngre förare är en större andel av äldre förares olyckor kollisioner mellan fordon i förhållande till singelolyckor. Äldre förare tenderar att i högre utsträckning vara ansvariga för sina olyckor. Den typiska situationen är när den äldre föraren svänger till vänster mot mötande trafik på en större väg och krockar med ett fordon som har företräde. Uppenbarligen upptäcker de inte motparten i tid och ger följaktligen inte företräde. Å andra sidan visar äldre förares relativt lilla andel av olyckor som icke-ansvarig part att de faktiskt har en långsam, konservativ och försiktig körstil som gör dem ”svårare att träffa” som oskyldig part jämfört med yngre, mindre defensiva förare.

Gällande äldre förare är ökningen av olyckor i korsningar så pass iögonfallande att mindre uppmärksamhet ges till det faktum att äldre förare är underrepresenterade i andra typer av olyckor som t.ex. singelolyckor när man tappar kontrollen över fordonet eller kollisioner pga. höga hastigheter eller farliga omkörningar. Minskningen av olyckor pga. höga hastigheter svarar mot förändringarna i körvanor hos äldre förare. Den stora andelen olyckor i korsningar tolkas ofta som ett tecken på den äldre förarens ökande svårigheter att hantera komplexa situationer. Inte lika ofta ses deras lilla andel avåkningar som ett tecken på mogen, säkerhetsmedveten körstil.

Varför är inte äldre förare lika lyckosamma när det gäller att undvika olyckor i komplexa miljöer, som i korsningar? Äldre förares huvudsakliga strategi för att underlätta bilkörning är att köra långsammare. När man tar sig igenom korsningar kan man ofta inte själv bestämma tempot. Svårigheterna påverkas både av korsningens design, men också av medtrafikanternas hastighet. Därmed kan äldre förare tvingas prestera under tidspress vilket kan övergå deras kapacitet.

Sammanfattningsvis: Det finns ingen ökad risk för äldre förare som grupp att råka ut för olyckor jämfört med medelålders förare. Äldre förare medför inte heller större risker gentemot medtrafikanter. Å andra sidan löper äldre förare betydligt större risk att bli allvarligt skadade eller dödade när olyckan väl är framme pga. deras större fysiska skörhet.

Åldrande och resande som en samhällelig folkhälsofråga

Åldrande och resande sett som en samhällelig hälsofråga har två huvudinriktningar: säkerhet och mobilitet. Problem med dessa båda leder till ogynnsamma konsekvenser för hälsan och kostnader för samhället. Tidigare har fokus till stor del legat på säkerhet, vilket är naturligt eftersom kostnaderna både för individen och samhället är uppenbara. Däremot är förhållandet mellan begränsad mobilitet och hälsoaspekter inte lika tydliga. Kort sagt: det är nödvändigt för en äldre person att leva ett aktivt liv och behålla hans eller hennes tidigare aktivitetsmönster; aktiva äldre är statistiskt sett friskare äldre än passiva; hälsa är direkt relaterat till funktionell kapacitet och äldre med god funktionell kapacitet har större möjlighet att leva autonomt och har mindre behov av allmänt stöd, vilket i förlängningen leder till en ekonomisk besparing. En genomgående analys av den ekonomiska betydelsen av god mobilitet utomhus för äldre behöver fortfarande göras för att vägleda beslutfattarnas strävan mot goda handlingsprogram för åldrande och transporter.

Åldrandets olika dimensioner

Åldrandet är en komplex process, som i alla åldersgrupper innebär både växande och förluster. De positiva aspekterna av åldrande underskattas, trots att man mer och mer uppskattar äldre som arbetskraft. Bland de positiva aspekterna av åldrande finns klokhet, strategiskt tänkande och mindre risktagande. Som bevis för detta kan man se att äldrepopulationen, trots den större andelen funktionsnedsättningar, har den lägsta olycksandelen av samtliga åldersgrupper.

Större interindividuella skillnader är en viktig effekt av åldrande. Därmed blir generaliseringar om individers prestation grundad i första hand på ålder tveksamma.

Med stigande ålder förändras ofta de sociala rollerna; t.ex. från förälder till mor/farförälder, från anställd till pensionär och från gift till änka/änkling. Samtidigt som de sociala rollerna förändras, förändras också relationen till den sociala omvärlden, vilket i tur kan leda till att attityder och värderingar kan ändras. Dessa sociala förändringar bland äldre kan ha en direkt påverkan på både det resande beteendet och behovet.

Bilkörning som en komplex färdighet

Traditionellt har bilkörning ansetts vara en uppgift som innebär komplext informationsprocessande. På senare tid har förståelsen av köruppgiften fördjupats. Körning har i ökande mån tolkats som en process som involverar kognitiva processer såsom målsättning och övergripande planering av aktiviteter samt andra högre beteendemönster. Då man betraktar bilkörning som en komplex färdighet blir det uppenbart att ett stort antal faktorer påverkar prestationen. Eftersom dessa faktorer inte enbart är psykologiska och kognitiva, utan också psykosociala och sociala är förutsättningarna för säker bilkörning inte enkla att definiera på ett täckande sätt. Vad gäller äldre förare har användningen av kompensationsstrategier viktiga implikationer för deras träning och bedömning, liksom för utformningen av fordon och vägar.

Att gestalta bilkörning som en komplicerad vardaglig färdighet har viktiga implikationer för förarbedömning, förarutbildning, liksom för utformningen av infrastruktur.

Fysiska åldersrelaterade förändringar och bilkörning

Här följer en kort genomgång av de fysiska åldersrelaterade funktionella förändringarna som anses viktigast för körprestationen.

I denna kontext menas med synfunktionen oftast synskärpa, känslighet för bländning och kontrastkänslighet. Synskärpa kan förbättras med ökad belysning och därmed skulle en del av problemen som äldre har kunna lösas genom att förbättra belysningen på vägarna. Det är dock osannolikt att detta skulle fungera som en trafiksäkerhetsåtgärd eftersom man inte har funnit något samband mellan synskärpa och olyckor. Däremot skulle ökad belysning kunna förbättra mobiliteten, genom att det kunde leda till behagligare bilkörning för äldre förare.

Grumlighet i linsen ökar risken för bländning. Problem med bländning är relaterade till svag belysning och dåliga reflektionsegenskaper i körbanan. Åldersrelaterade försämringar i kontrastkänslighet kan orsaka svårigheter för äldre förare att avläsa vägmärken. Skyltar med symboler föredras därför i motsats till sådana med text.

Uppmärksamhet är högst relevant i fråga om åldrande och bilkörning. Köruppgiften kräver att man kan dela uppmärksamheten mellan flera olika saker, inte minst i mer komplicerade trafiksituationer som korsningar. Äldre har visat sig ha större svårigheter att filtrera bort oväsentliga stimuli. Sambanden mellan uppmärksamhet och åldrande kan delvis förklara problemen som äldre får i korsningar och andra komplicerade trafiksituationer. Både reaktionstiden och den motoriska förmågan försämras med stigande ålder. Reaktionstider till enkla stimuli försämras inte dramatiskt, men däremot vid beslutsfattande i komplicerade situationer.

Bland de vanligaste åldersrelaterade sjukdomarna ingår reumatism, hjärtsjukdomar, högt blodtryck och diabetes. Hjärtsjukdomar innebär en viss risk för trafiksäkerhet. Man har funnit att efter sjukhusvistelse för hjärtsjukdom minskar bilkörandet och så småningom minskar också mobiliteten. Diabetes och bilkörning har studerats mycket. Nya forskningsrön har visat att patienter med diabetes inte löper ökad risk att råka ut för olyckor om inte sjukdomen är av en allvarlig karaktär.

Demens orsakar försämring av de kognitiva förmågorna liksom bedömningar som kan visa sig genom svårigheter vid bilkörning. Demenssjukdomar är degenerationssjukdomar men beroende på vilken typ av demens kan det dröja ett till tio år innan körförmågans försämring blir uppenbar. Kognitiva svårigheter och demens associeras med svårigheter vid bilkörning, minskande eller upphörande av bilkörning. Långt gången demens kommer att medföra en oförmåga att hantera bilen. Effekten av förare med demens på trafiksäkerhet är mycket svår att slå fast empiriskt. Dessutom är det svårt att beräkna olycksriskerna empiriskt. Trots detta, verkar demens och andra relaterade tillstånd leda till en begränsning av bilkörande vilket får det att framstå som att detta är ett ganska litet problem för trafiksäkerheten i stort.

Riktade säkerhetsåtgärder mot äldre – restriktiva åtgärder

Den vanligaste frågan i form av säkerhetsåtgärder mot äldre bilförare är begränsning av bilkörning, framförallt genom att identifiera och förbjuda dem som anses för "farliga" att köra. Men hur ska vi veta vilka förare som innebär för stor risk? Genom att bilkörning är en så komplicerad uppgift, kan försämringar i någon egenskap kompenseras genom en förändring av beteendet.

Om vi ville utesluta bilförare med hög risk från trafiken borde vi hitta indikatorer som predicerar säkerhet. Det finns varken etisk eller vetenskaplig grund att utesluta individer från bilkörning om de inte innebär en högre olycksrisk. Därför bör diagnostiska kriterier för uteslutande valideras mot olyckor. Detta innebär stora svårigheter eftersom olyckor, på individnivå, är ovanliga.

Åldersrelaterad screening är ofta föreslagen som en effektiv säkerhetsåtgärd. Denna baseras dock på missuppfattningen att äldre förare är en högriskgrupp. Principen skulle vara att med jämna intervall "kolla" körkortsinnehavare efter en viss ålder för att exkludera de förare som har en högre olycksrisk. Denna idé kommer upp gång på gång och har en falsk innehållsvaliditet och erbjuder många affärsmöjligheter. Trots detta har inga seriösa studier för att utvärdera säkerhetseffekter av åldersbaserad förarscreening lyckats få fram några fördelar (för en översikt, se OECD, 2001).

Riktade säkerhetsåtgärder mot äldre förare – stödjande åtgärder

Allteftersom vikten av självständig mobilitet för äldre har erkänts, har antalet säkerhetsåtgärder av mer stödjande natur ökat. Dessa inkluderar utbildning och "avrostningskurser" för äldre förare och rehabilitering av förare som pga. hälsoaspekter har fått minskad körförmåga. Den ökande kunskapen om positiva effekter av t.ex. kompensatoriska strategier i bilkörning har lett till en ökning av kurser och utbildningar för äldre förare. Dessa kurser och utbildningar är generellt sett ganska nya, grundade på 1990-talet och ännu finns inga publicerade systematiska utvärderingar av dessa.

Riktade säkerhetsåtgärder mot äldre förare – vägarnas design

Äldre förare skiljer sig inte dramatiskt från medelålders bilförare med avseende på körprestation. Däremot har äldre förare som grupp större svårigheter, framförallt i komplicerade trafiksituationer, jämfört med yngre, erfarna förargrupper. Det finns flera åtgärder som förbättrar säkerheten för äldre vad gäller vägarnas utformning och design. Dessa åtgärder påverkar alla förare positivt, oavsett ålder. Här fokuserar vi på vikten av vägarnas utformning mer generellt genom att presentera ett antal principer. För information om specifika utformningar som är bäst för äldre hänvisar vi till avsnittet "Road design" i rapporten.

Generella principer för vägars utformning

Några generella principer baserade på empirisk kunskap och samlad erfarenhet kan formuleras. Dessa principer gäller för alla vägtrafikanter men är av särskild vikt för äldre.

1) Väg skall byggas med en för trafikanten uppenbar och entydig funktion och i ett standardiserat utförande, så att trafikantens förväntningar på vägens fortsättning och på medtrafikanternas beteenden bekräftas.
2) Vägmiljön skall innehålla så mycket redundant information som möjligt. Med andra ord innebär detta att alla element i vägen och vägmiljön ska interagera så informationen om vägens funktion är tydlig och omisskännelig.
3) En korrekt utformad vägmiljö skapar dels korrekta förväntningar hos bilföraren och dels stödjer det en effektiv informationsinhämtning genom att skapa goda förutsättningar för ett automatiserat körbeteende.
4) Väg skall utformas så att trafikanten ges tillräcklig tid att utföra en krävande uppgift i taget.
5) Vägkorsningar skall utformas så att trafikanten utan svårighet förstår korsningens utformning. Föraren skall hela tiden se/uppleva var hon befinner sig i korsningen.
6) Väg skall utformas så att förarens arbetsbelastning varken blir för hög eller för låg. I normala fall bör belastningen i korsningar minskas och belastningen mellan dem öka.
7) Vägmärken skall stå i de positioner utefter vägen där föraren är i behov av informationen, där den kan tolkas (i relation till vägen) och där förarna har tid att avläsa dem.
8) Att finna vägen till resans mål är en strategisk problemlösningsuppgift. Detta innebär att vägvisningsinformationen måste vara konsekvent samt logiskt och hierarkiskt uppbyggd.
9) Vägens informationssystem för förarens taktiska beslut skall vara tydliga och kunna upptäckas på tillräckligt långa avstånd. Vägmarkeringar och andra element som ska stödja de operationella besluten bör på motsvarande vis bli synliga i tillräckligt god tid för att kunna anpassa fordonsmanövrar.

Riktade säkerhetsåtgärder mot äldre förare – fordonets utformning

Många av de åldersrelaterade fysiska förändringarna och försämringarna påverkar inte den observerade kvaliteten på körprestation men kan påverka den subjektiva körprestationen. Körkomforten kan, trots detta, förbättras med god utformning. Bättre utformning för att underlätta för den äldre föraren att ta sig in i eller ut ur bilen har föreslagits. Mer anpassningsbar utrustning i bilen kan leda till att föraren kan koncentrera sig på själva köruppgiften i större utsträckning.

En annan typ av design är att skydda förare och passagerare genom passiv säkerhet. Detta innefattar skyddsutrustningar såsom som säkerhetsbälten och krockkuddar samt förbättrade krockegenskaper. Framförallt äldre förare vinner på dessa förbättringar, men äldres speciella behov bör tillgodoses i framtida utformningsprocesser.

Intelligenta Transport System (ITS) omfattar ett vitt spektrum av kommunikationsbaserad informations-, kontroll- och elektronisk teknologi i bilar. Utvecklingen av denna teknologi började på 1980-talet. Sedan dess har det funnits stort hopp om att denna teknologi skulle introduceras på marknaden i olika tillämpningar inom ett fåtal år för att öka säkerheten och kapaciteten markant. Ännu har inte dessa förväntningar uppfyllts. Förväntningarna har visat sig väl optimistiska mot bakgrund av de små förbättringarna som skett. Därför väntar vi fortfarande på bra ITS-baserade hjälpmedel på marknaden.

En viktig egenskap av ITS-utrustning är att det inte får läggas någon extra ansträngning på föraruppgiften för att förenkla äldre förares körande. Faktum är att utvecklingen av ITS-utrustning och prototyper har varit teknologistyrda snarare än förarstyrda. Av denna anledning verkar det osannolikt att den första generationens ITS-utrustning på marknaden kommer att uppfylla detta krav och förenkla bilkörningen för äldre.

Slutsatser och rekommendationer

1) Äldrepopulationen (65+) kommer att växa från ca 15 % år 2000 till ca 30 % år 2050.
2) Äldre förare som grupp kör lika säkert som unga, erfarna förare.
3) Äldre förare innebär inte en ökad risk för sina medtrafikanter.
4) Screening av förare från en viss ålder är inte en effektiv åtgärd för att öka trafiksäkerheten.
5) När äldre förare råkar ut för en olycka löper de större risk att bli svårt skadade eller dödade än yngre åldersgrupper. Detta eftersom den fysiska skörheten ökar med åldern.
6) I jämförelse med andra former av transporter är bilkörning säker även för de äldre.
7) Trafiksäkerhet bör ses i ett folkhälsoperspektiv för att balansera kraven från den åldrande populationen med avseende på både mobilitet och säkerhet.
8) De äldre medborgarnas mobilitet genom bilkörning kan ökas genom att stödja fortsatt bilkörning, framförallt för äldre kvinnor, liksom genom att förbättra bilarnas och vägarnas utformning.

1 Introduction

"Older drivers" as a research question is a child of its time, a social and historical construction, as – of course – are all research questions. During the history of private car driving, prevailing views on both ageing and the threats and problems related to driving have evolved. In the following, we attempt to give a historical perspective to the subject of the present report by describing the history of older driver research. We thereby assume that the evolution of the research questions is a reflection of the society's changing views on older drivers as a potential problem. For obvious reasons, our analysis and the present report mainly reflect the situation in industrialised countries.

1.1 History of older driver research

The "older driver problem" first became established as a result of a wave of intensive research activities on older drivers by the end of the sixties, mainly in the U.S. As a result of these efforts (for an overview, see Grow, 1972), general trends in accident rates and exposure characteristics were established. Thus, it was found that older drivers had less accidents per capita but more per mileage and that they in general drove less than did middle-aged drivers (Finesilver, 1969; McFarland, 1964; Planek, 1972). The importance of different aspects of vision for safe driving was thoroughly studied by Hills and Burg (1977).

At the North Carolina Symposium on Highway Safety in 1972, Planek (1972) summarised the status quo in a critical review the focus of which he defined in the following manner:

> *"In studying the effect of the ageing process on driving, we shall be primarily interested in drivers over 55 years of age, although some age-associated change in driving activity itself may start as early as 50. This discussion will focus on defining the deficiencies of ageing drivers and examining them in relation to driving performance research. Hopefully, from such a review, we can begin to assess the impact of the ageing driver in today's traffic both quantitatively and qualitatively." (p. 4)*

According to Planek, summarising the findings available, the deficiencies of the ageing driver seemed to fall into two overlapping categories: those due to the ageing process itself and those due to some medical disability. The age-related deficiencies were delineated along three general areas: sensory reception, neural processing and transmission, and motor response. Planek's views reflected the Zeitgeist in research on ageing drivers in two ways. First, in harmony with the concurrent interest in accident proneness (Echterhoff, 1990), the driver's "deficiencies" were seen exclusively as the cause of all problems, and the characteristics of the traffic system were taken largely for granted. Second, the concepts used for the driver's internal faculties clearly date from a period before the "cognitive revolution"; the lack of an information-processing viewpoint and cognitive terminology is flagrant for a modern reader. Another analysis presented at the same meeting reflects similar thinking (Mann, 1972). Although discussion about the importance of decision making processes and about possible safety-related changes in the traffic system soon emerged (Planek & Overend, 1973), the general recommendations made by the U.S. National Conference on the Ageing

Driver (NCAD, 1974) were dominantly oriented towards screening drivers and eliminating those with higher risk from the driver population.

Once it had been settled that there was, or would be, an “older driver problem”, research in the eighties was directed toward a more thorough understanding of the general traits of this problem. Early findings on accidents were supported and completed by later studies. Thus, it was shown that older drivers are "good insurance risks" (Cooper, 1990; Wiener, 1972) but have more accidents per distance driven (Brorsson, 1989; Cerelli, 1989; Evans, 1987; 1988; Graca, 1986). When involved in an accident, older drivers were found to be more often the legally responsible party, i.e., the party at fault (Knoflacher, 1979; McKelvey & Stamatiadis, 1989; Partyka, 1983; Verhaegen, Toebat, & Delbeke, 1988; Viano, Culver, Evans, & Frick, 1990). Older drivers were shown to be overrepresented in accidents occurring in intersections and other complex traffic situations (Broughton, 1988; Cerelli, 1989; Hauer, 1988; OECD, 1985; Partyka, 1983; Stamatiadis, Taylor, & McKelvey, 1991; Viano et al., 1990; Yanik, 1985) and to be more often convicted for corresponding violations in traffic (McKelvey & Stamatiadis, 1989; Rothe, 1990). On the other hand, they turned out to have less single-vehicle accidents (Campbell, 1966; Cerelli, 1989; Moore, Sedgley, & Sabey, 1982). It also was settled that the accidents of older drivers mostly occurred in daytime (Broughton, 1988; Campbell, 1966; Cerelli, 1989; Hauer, 1988) and that accident-involved older drivers were less often alcohol-intoxicated than accident involved young or middle-aged drivers (Berghaus, Pieper, & Staak, 1983).

While the Results sections of the research papers of this period usually are neat and straightforward, the Discussion sections tend to be disappointing. Attempts to explain the emerging accident picture of older drivers were mostly based on an ad hoc combination of elements belonging to the following three knowledge bases: (1) a task analysis of car driving, now mostly described in information processing terms (e.g., flow charts), (2) gerontological data about age-related changes in different aspects of human performance, and (3) accident statistics. From these three databases, hypothetical explanations were generated by matching the information about which faculties are necessary for safe driving, which functions change with age, and which kinds of accidents occur. The elements chosen to explain the accident picture were mostly picked on the basis of their face value. Thus, since (1) vision certainly is one of the necessary faculties for safe driving, and (2) several visual functions deteriorate with age, and (3) older drivers were overrepresented in intersection accidents where they failed to see their collision partners in time, age-related changes in vision often were blamed for their accidents.

A central weakness of such an approach was, of course, that although empirical evidence of the nature of the accidents accumulated, insights into their causation did not, since the same speculations were expressed again and again with little or no effort towards deepening the understanding of the behavioural mechanisms mediating the effects of functional deficits via driving behaviour to accident statistics. A definite improvement, however, compared to earlier research, was a shift of focus towards higher cognitive functions in search of factors explaining the age-related accident risk. During the seventies, sensory and motor phenomena were the focus; during the eighties, critical deficiencies were described in perceptual rather than sensory terms, and referring to attention rather than reaction times or motor speed. Neural conduction time was mercifully forgotten as a major factor explaining accidents.

While the adaptation of a cognitive frame of thinking was a major improvement, the main weakness of “modern” flow chart models of driver behaviour was their ahistorical nature. Such models only presented a snapshot of the actual driving task and failed to take into account the nature of driving as a skilled performance with a long learning history. Conceptualising driving as skilled behaviour rather than, or in addition to its being a complex information processing task has become increasingly popular since the beginning of the nineties. At that time, some important advances also were made in the study of ageing of cognitive skills (Bosman, 1993). This approach certainly shows promise toward a deeper understanding of the weaknesses, strengths, and compensatory strategies of older drivers.

One of the corner stones of the definition of the older driver problem, the claim concerning their higher accident rates, was contested in the eighties when it was pointed out that a higher risk of injury leads to sampling bias in accident data bases. As demonstrated by Evans (1991) on the basis of several earlier studies, the greater physical frailty of older individuals explains an important part of their higher rates of injury and fatal accidents. Challenging the traditional problem definition, Evans concluded that for older drivers, accident risk in fact was a minor issue, and limitations in mobility, due to self-imposed compensatory restrictions in driving exposure, were the real problem.

An important turn in the research appeared in the late 1980’s, shifting focus from a general approach toward a differential one. Research efforts in the eighties had attempted to describe the general nature of the older driver problem. However, it was at the same time increasingly recognised that the problem may not be a general one. Gerontological research had long since shown that interindividual variance in most performance variables increases with age. Clinical experience pointed out certain subgroups of older patients having illnesses that could affect abilities essential for safe driving as a major source of safety concern, rather than persons suffering from nothing more than “normal ageing”. Thus, while earlier research mostly was guided by the question "Why do older drivers have higher accident risk?" the alternative question "Which older drivers have higher accident risk?" gained momentum in the 1990’s (Hakamies-Blomqvist, 1998). Since then, an important body of research has been produced on different aspects of age-related illnesses and driving.

During the last few years, the area of ageing and transportation generally speaking has both expanded and gained in importance. There have also been some important shifts of orientation. A major change can be seen in the overriding problem definition: why is research needed, what is the societal issue where policy makers need guidance from scientific evidence? Earlier, the question of ageing and transportation, especially for drivers, was mostly articulated in terms of safety alone. Lately, the issue of mobility has increasingly become a primary concern, with safety regarded as one of its quality dimensions together with other important dimensions such as cost-effectiveness and sustainability. This change of focus is well exemplified by the two latest OECD reports on ageing and transportation. The earlier one, from 1985, was entitled *Safety of older road users in traffic* and had rather a narrow scope, whereas the one from 2001 is called *Ageing and transportation: Mobility needs and safety issues*, and has a clear ambition to set things in a wider perspective.

In ongoing research activities, we can notice two parallel and complementary trends. On one hand, the scope and perspectives of research have broadened. In harmony with the WHO emphasis on Active Ageing, the question of senior mobility now is conceived as a major societal issue with both economic and ethical aspects, and with many and complex interrelations with other major societal areas such as social and health care issues, land use planning, intelligent housing, etc. On the other hand, research questions have both sharpened and deepened. Until rather recently, the research agenda was largely directed towards a general description of "transportation safety in the ageing societies". Currently, we see the effects of an increasing realisation that many of the key issues are not general in nature. Ageing citizens with transportation needs and preferences are not just "older road users", they are men and women, rural and urban inhabitants, rich and poor, healthy and sick – well-informed policy decisions therefore must lean on a research-based knowledge base covering the diversity of the current and future ageing users of transportation. As a corollary to this, we can see an increasing methodological diversity. Not all questions can be meaningfully approached through the classical mainstream approaches of traffic safety research, which for a long period of time dominated even traffic gerontology. Some questions are social or cultural in nature and must be addressed accordingly. There are also questions that are important for our overall understanding of this complex area but may only be scientifically approachable through qualitative methods.

When discussing older drivers' accidents (see chapter 2.3) it is evident that the compensation view on accident causation is more relevant than the victim view.

The evolution of the "older driver problem" reflects the development in theoretical thinking on driver behaviour and accident causation. The earlier "victim theory" (Brehmer, 1984) postulated that drivers having accidents were victims of a system that is too demanding. This view was predominant in 1960–1980. However, following a number of large epidemiological studies that failed to find positive correlations between different kinds performance measures (such as vision, as in (Burg, 1967; Burg, 1968) and accident risk, the simplistic victim theory was gradually replaced by a new theoretical view focusing on compensation. The central idea is that driving is a self-paced task. Drivers make choices that influence the difficulty of the driving task, such as driving slower. In this manner, they can compensate for different kinds of performance deficits. Compensation can however also work to the opposite direction. One of the earliest examples of this is given by (Gibson & Crooks, 1938) who state that a driver whose car gets better brakes can adjust their safety margin to the previous target level by increasing their speed or diminishing the distance to the car in front. Later, this line of thinking has been developed by Gerald Wilde under the concept of "risk homeostasis".

1.2 Who are the older drivers of today and tomorrow?

It has been projected that in the future the older driver population will increasingly consist of drivers aged 75+, of women drivers, and of active drivers with greater annual mileage (see e.g. Burkhardt & McGavock, 1999; UK Department for transport, 2001b). The older driver population in the future will thus most probably differ from the older drivers of today, as we know it. The expected quantitative and qualitative change in older drivers also has influenced research. There is increasing interest to focus research especially on the oldest old (80+) drivers and on older women drivers.

Changes in the general discourses on ageing and the aged have played a part in directing research to acknowledge the great diversity of the older driver population. First, the definition of old age in terms of chronological age has changed within the last decades: the boundary mark dividing adulthood from old adulthood has changed from 55–65 years to 75–80 years. In addition, late adulthood often is divided into “third” and “fourth” age, where the third age refers to the active, independent and healthy period of life after retirement, and the fourth age to the last period of life with developed disabilities and increasing dependency on other people. Similarly, in traffic research, the focus of studies on older drivers has increasingly shifted from those aged 65+ to those aged 70+ or 75+. This has been supported by the fact that age-related changes affecting driving usually do not become marked before the age of 75 (excluding the impact that retirement on average has on travel patterns). Findings from previous research support this, showing that in later cohorts the elderly-typical accident patterns appear at later ages than in the earlier cohorts (Hakamies-Blomqvist & Henriksson, 1999).

Second, recent trends in the fields of gerontology and social science have emphasized the overall diversity of the older population in terms of lifestyles and consumption culture. Especially marked differences regarding this can be found between different cohorts of older persons. These considerations also have influenced traffic research: increasing attention is directed towards predicting future changes in travel behaviour and travel choices, driving habits, and mobility options in older population. For example, some studies have already tried to forecast the impact the predicted overall increase in active driving in the older driver population will have on traffic safety and traffic fatality numbers (Bédard, Stones, Guyatt & Hirdes, 2001; Burkhardt & McGavock, 1999; Lyman, Ferguson, Braver & Williams, 2002; UK Department for Transport, 2001b).

1.3 The aim of the present study

The aim of the present literature review is to produce an updated report on older drivers. We shall place special emphasis

- on drivers aged 75 and above,
- on the overall diversity of the older population (including gender aspects),
- on infrastructure development from an older driver perspective and
- on different types of safety measures and their effects.

We shall also make an effort to clarify certain conceptual and theoretical issues and to present an overall view of this research area that is based on methodologically sound research. In general, the present review focuses on drivers and road users aged 75 and above, but literature regarding persons aged 65+ is referred to when relevant to the issues under discussion.

The report consists of four main chapters. We begin with a general description of the travel characteristics of the older road users and drivers aged 75+ and the implications of these characteristics for mobility, safety, and security. We also outline projected or expected future changes related to these characteristics. In the second chapter, we focus on ageing and the driving task, and the implications that age-related functional changes may have on performing the driving task. In the third chapter, we discuss safety measures that have the older drivers themselves as targets, dividing these measures into restrictive policies and supportive actions. In the fourth chapter, we describe measures targeting the traffic infrastructure, including road and vehicle design and ITS applications.

The material for this review was collected from the following sources. As a starting point we had the results of several recent internet-based database searches performed in connection with other recent project on the same area. We completed and updated these using the internet-based databases TRAX, which covers VTI's library; and the medically oriented PubMed. In addition, we used the authors' own personal research literature libraries and international networks to gain access to findings not yet available in published form. In order not to make the reading of the report very heavy however, we have chosen the strategy of substantiating our text with a few selected, representative examples for every topic, rather than producing exhaustive lists of all available literature.

A central ambition for the present work has been to produce a balanced view on older drivers as a societal issue, based on sound scientific evidence and rectifying earlier misconceptions due to methodological biases and an insufficient system perspective. We identified this as an important task since there are severe weaknesses in this respect in many earlier studies on older drivers.

With this caveat in mind, we would wish to indicate a couple of recent reports and literature reviews on older road users that we found useful. They have somewhat differing perspectives and can provide additional information on specific issues for an interested reader. These publications are listed below:

Holland, C. (2001). *Older drivers: A review*. London: Department for Transport, Local Government Regions.

- This review focuses mostly on aging and functional capabilities in relation to driving.

Metropolitan Transportation Comission (2002). *San Francisco Bay Area Older Adults Transportation Study. Final Report*. San Francisco, CA: Nelson/Nygaard consulting Associates.

- This publication reports results from San Francisco Bay Area Older Adults Transportation Study, which focused on the transport options of the area, regional planning, and mobility and mobility barriers of older adults. The report can be found also on-line, at:
  http://www.mtc.ca.gov/publications/oats/index.htm

OECD (2001). Ageing and Transport: Mobility needs and safety issues. Paris: OECD.

- This report gives a comprehensive picture on older road users issues, with main focus on driving. The topics in the report vary from accident analysis to vehicle design, with focus on how to meet the safety and mobility needs of an ageing population.

OECD (2000). *Transport and the ageing of the population*. Roundtable 112. Paris: OECD.

– This report comprises of five national reports (the US, Germany, Italy, Norway, and the UK) on the transport options and issues of older road users.

Rabbitt, P., Carmichael, A., Shilling, V. & Sutcliffe, P. (2002). *Age, health, and driving*. Basingstoke: AA Foundation for Road Safety Research.

– This publication reports longitudinally observed data on older drivers and their driving habits and experiences in relation to changes in health status.

Sirén, A., Heikkinen, S. & Hakamies-Blomqvist, L. (2001). *Older female road users: A review*. VTI rapport 467A. Linköping: VTI.

– This report focuses on older women as road users. The report comprises of a theoretical part introducing basic concepts of gerontology, women's studies, and traffic research, and a literature review part.

UK Department for Transport (2001a). *Older people: Their transport needs and requirements.* On-line report, published 12 February 2001. http://www.mobility-unit.dft.gov.uk/older/needs

– This on-line report focuses on mobility and mobility needs. The report emphasizes the importance of mobility for older persons but approaches the issue mainly from viewpoint of public transportation and public services.

UK Department for Transport (2001b). *Forecasting older driver accidents and causalities*. Road Safety Research Report No. 23. London: UK dept. for transport.

– This report aims to estimate the development of safety situation in the future as the population ages. Though its conceptualisation of the risk of older drivers is insufficient, it provides good forecasting data on the travel patterns and driving habits of the older drivers.

2 Seniors in the transportation system: Travel habits and implications for mobility, safety, and security

2.1 Travel patterns

2.1.1 Trip patterns

With age, travelling and trip rates decrease. With retirement especially, daily travel decreases considerably as there are fewer work-related trips. Even within the older driver group, increasing age predicts decreasing travel (Brög, Erl & Glorius, 2000; Hjorthol & Sagberg, 2000; Oxley, 2000; Rosenbloom, 1995; 2000). According to European studies, the most marked decrease in travel outside home takes place after the age of 70 years (Brög et al., 2000; Hjorthol & Sagberg, 2000; Oxley, 2000; Sirén & Hakamies-Blomqvist, 2001). An American study however reported no significant changes in either distance per trip travelled or annual mileage driven before the age of 77 and over (Benekohal, Michaels, Shim & Resende, 1994). The sharp decrease in car use after the age of 70 found in many studies (e.g., Brög et al., 2000; Marcellini, Gagliardi & Leonardi, 2000; Sirén & Hakamies-Blomqvist, 2001) may reflect the license renewal policies in several countries: in many EU member countries the age for an obligatory renewal of the driver license is 70 years (White & O'Neill, 2000).

Compared to other age groups, persons aged 75 and above drive less and use other modes of transportation more (Brög et al., 2000; Oxley, 2000; Rosenbloom, 1995). The proportion of older persons driving has however increased during the last decades, and a continuing increase is expected (e.g., UK Department for Transport, 2001b). In Sweden, between the years 1990 and 2002, the proportion of those holding a driver license in the age group 80+ increased from 58.3% to 83.6% among men and from 9.6% to 32.5% among women (Bilindustri-föreningen, 1990; Bil Sweden, 2002).

2.1.2 Gender differences

In all age groups, women travel less than men. So even in the population aged 75 and above: women travel overall less than men and fewer women than men hold a driver license (Benekohal et al., 1994; Brög et al., 2000; Oxley, 2000; Rosenbloom, 2000; Sirén & Hakamies-Blomqvist, 2001). The older the age group, the smaller share of the women are licensed to driver. This gender difference is more marked in European countries than in the US (Rosenbloom, 2000). In the US, automobilisation has a longer history and it also became common for women to drive earlier in the US than in Europe. Even in Europe, the gender difference in licensing rates is cohort-related and will diminish when the baby-boom generations reach old age (e.g. Spain, 1997). Whether or not it will entirely disappear will, among other things, depend on future trends in driving cessation among older women (see the below section on driving cessation).

2.1.3 Consequences of older persons' travel patterns for mobility, safety, and security

Not all of the age-related decrease in travel outside home is due to age-related lifestyle changes such as retirement. Some of it may reflect decreased access to convenient personal mobility options. For example, a Finnish study found that older persons, especially those aged 75 and above, and especially women, often would have done more trips if it had been practically feasible (Sirén & Hakamies-Blomqvist, 2001). In this study, experience of sufficient personal mobility was strongly related to the option to drive. Findings by Hjorthol and Sagberg (2000) also support the idea that a decrease in driving risks to lead to a decrease in overall mobility and that the age-related decrease in travel is not solely based on personal choices but also reflects age-related mobility barriers.

Private car driving does not only seem to be closely related to maintaining satisfactory levels of personal mobility, but also to safety and security. Compared to other modes, driving is a safe travel mode for older persons. When compared to their share of the population, older persons are overrepresented in casualties when using public transportation, and as pedestrians (Hakamies-Blomqvist, 2003; OECD, 2001). In western Europe, older pedestrians account for 45% of the pedestrian fatalities while representing only 15% of the whole population (OECD, 2001). According to various studies (see Fontaine & Gourlet, 1997; Sjögren et al., 1993; Oxley et al., 1995) traffic situations where older pedestrians are at most risk include crossing an undivided street in a busy location in urban areas. The consequences of accidents as unprotected road user are severe due to the increasing frailty of the ageing body and also to the fact that there is no external protection. Inconsequence, the fatality ratio of traffic casualties increases sharply with age, and especially so for older pedestrians (Hakamies-Blomqvist, 2003).

Issues related to personal security become more relevant when walking, biking, or using public transportation (cf., Atkins, 1989). Threat of violence on the streets or in the public transport system or threat of being hit by vehicles is a concern of older persons (Sirén & Hakamies-Blomqvist, 2002) that can furthermore lead to decreased mobility.

2.2 Driving habits

2.2.1 Older drivers' driving preferences

In general, compared to younger drivers, older drivers drive less (e.g. Benekohal et al., 1994; Rosenbloom, 1995) and with lower average speeds (e.g., Chipman, MacGregor, Smiley & Lee-Gosselin, 1992). In both accident analyses and driving behaviour surveys, older drivers have been found to be more likely to modify their driving by avoiding difficult driving conditions, like rush hours, darkness, bad road-surface conditions (Chipman, MacGregor, Smiley & Lee-Gosselin, 1993; Hakamies-Blomqvist, 1994a; Rothe, 1990; Wiktorsson, 1987; see also Holland, 2001). This has generally been interpreted as behavioural compensation for different age-related problems in driving (e.g. Brouwer, Rothengatter & Wolffelaar, 1988). However, not all changes in driving habits reflect compensatory behaviour but rather the wider array of choices in relation to travel times and weather conditions that is associated with retirement and other age-related life style changes (OECD, 2001). Most of us, independently of age, prefer driving on day-time and in good weather conditions, if given the choice.

2.2.2 Driving-related experiences and attitudes

Older drivers experience an increasing amount of problems in certain traffic situations after the age of 75, including left turns, signalized intersections, and stop sign intersections (Bishu, Foster & McCoy, 1991; Rimmö & Hakamies-Blomqvist, 2002). To some extent this may be due to physical changes that make driving uncomfortable; driving difficulty in the elderly is related to the number of their medical conditions (Lyman, McGwin & Sims, 2001). In addition, the tendency to perceive and interpret traffic situations as more risky and to take fewer risks also has been found to increase in older age groups (Sivak, Soler & Tränkle, 1989a; 1989b).

When assessing themselves as drivers, older drivers as a group think of themselves as cautious, courteous, and good drivers as compared to young ones (Nelson, Evelyn & Taylor, 1993). Marottoli and Richardson (1998) studied drivers aged over 77 years, and found that the majority of drivers rated themselves as above average. Those older drivers assessing themselves as much better than other drivers also had higher confidence on their driving ability (Marottoli & Richardson, 1998). A classical finding when drivers are asked to assess themselves as drivers is that most of them rate themselves as better than average drivers (Svenson, 1981); thus this is not a surprising finding. Older drivers in general have, however, been found to have less illusory self-assessments than younger drivers when comparing themselves with their peers at the same age (Matthews & Moran, 1986), or if driving experience is controlled for (Sivak et al, 1989b). This signalises a good level of self-evaluation skills in the elderly. On the other hand, Holland and Rabbit (1992) found older drivers to be relatively unaware of their sensory and cognitive deficits when assessing themselves as drivers. However, this need not affect their safety: several recent studies have found experienced difficulty in driving to be related to voluntary reduction and cessation of driving (e.g., Lyman et al., 2001; Rimmö & Hakamies-Blomqvist, 2002).

2.2.3 Driving cessation

Various aspects of driving cessation in old age have been studied during the last decade. Both the reasons for and the consequences of driving cessation have been studied. In general, the findings from both US and European studies are similar, although in North America, drivers tend to stop driving at a higher age than in Europe and the mobility consequences tend to be more severe, probably reflecting that continent's greater car dependency.

In the United States, the proportion of persons limiting or stopping their driving starts to increase from the age of 70 years (Burkhardt, Berger, & McGavock, 1996). However, an earlier US study reported a mean age of 85.5 years for driving cessation (Dellinger, Sehgal, Sleet & Barrett-Connor, 2001). Earlier statistics from the US also show that the proportion of drivers in the age group 75–79 is still 93% for males and 71% for females and in the age group 85+, 80% for males and 37% for females (Federal Highway Safety Administration, 2002). The European situation is somewhat different. In a British study, the mean age for driving cessation was 72 years (Rabbitt, Carmichael, Jones, & Holland, 1996) and a Swedish study reported drivers 75+ to significantly reduce their driving (Rimmö & Hakamies-Blomqvist, 2002). In Europe, the rates for licensed drivers among older persons are markedly lower than in the US: Oxley (2000) reports 64% of British men and 19% of women to hold a driver license in the age group 75–79, and 39% of men and 4% of women to hold a license in the age group 85+. However, according to the latest Swedish licensing rate statistics (Bil Sweden, 2002) 84% of men and 33% of women aged 80+ hold a driver license. The situation in Sweden thus resembles that of the US.

Women tend to give up their licenses at a younger age than men (Hakamies-Blomqvist & Wahlström, 1998; Rimmö & Hakamies-Blomqvist, 2002) and compared to men, more often voluntarily (Hakamies-Blomqvist & Wahlström, 1998; Jette & Branch, 1992; Stewart, Moore, Marks, May, & Hale, 1993). In general, women are also in better health than men when they give up driving (Hakamies-Blomqvist & Wahlström, 1998), and are likely to be physically fit to continue driving when choosing to give up (Sirén, Hakamies-Blomqvist & Lindeman, 2004). However, recent US research indicates some change in this gendered pattern: Dellinger et al. (2001) reported that 80 percent of the drivers who had given up driving had done it in their 80's or 90's, and in this sample of ex-drivers two-thirds were women. More than half of the studied sample mentioned medical problems as the main reason to stop driving. Forrest et al. (1997) also reported medical problems to be related to driving cessation in very old women. These findings may indicate a change in the driving patterns of older women as their accumulated driving experience approaches that of men (c.f., Spain, 1997).

For men, the main reason to give up driving is bad health (Hakamies-Blomqvist & Wahlström, 1998). The health conditions most often related to driving cessation are heart problems, neurological diseases, cognitive impairment, and eye problems (Campbell, Bush & Hale, 1993; Freund & Szinovacz, 2002; Foley, Masaki, Ross & White, 2000; Gilhotra, Mitchell, Ivers & Cumming, 2001; Hakamies-Blomqvist & Wahlström, 1998; Peel, Westmoreland & Steinberg, 2002). In a study on very old drivers (84 years and above) Brayne et al. (2000) found that those persons still driving had very few limitations on their daily activities and were not cognitively impaired. Although the increase in the number of medical conditions is related to decreased driving, men are more likely than women to continue driving in spite of increasing health problems, e.g., decreased cognitive performance level (Freund & Szinovacz, 2002).

Certain social factors also play a part in the decision to stop driving. Besides gender, marital status and household size have been found to influence driving cessation. Married persons and those living in smaller households are more likely to continue driving (Chipman, Payne & McDonough, 1998).

Driving cessation is likely to reduce mobility and negatively affect the quality of life. The consequences have been described to be mostly negative. Driving cessation has been found to decrease the amount of out-of-home activities (Marottoli et al., 2000) and to be related to increased depression (Fonda, Wallace & Herzog, 2001; Marottoli et al., 1997). It has also been argued that giving up driving has negative impacts on older person's identity, feeling of independence, and dignity (Bonnel, 1999; Burkhardt et al., 1996; Eisenhandler, 1990; Peel et al., 2002). Taylor and Tripodes (2001) also reported family members and other caregivers to face a considerable responsibility for meeting the transport needs of older persons giving up driving due to dementia, which indicates a lack of valid transport options for cognitively impaired older persons.

2.2.4 Gender differences

The previous section on driving cessation described the most marked difference in older women's and men's driving habits: older men keep driving up to a high age more often than older women. The reasons why older women are more likely to retire from the wheel earlier and for less pressing reasons are not fully clear, but it is reasonable to assume that the gendered nature of driving cessation reflects the gendered nature of the whole past driving career. That is, women have during their driving career been subjected to more conservative views on gender roles regarding driving and have gained less driving experience both quantitatively and qualitatively than men. This in turn is reflected in women's experiences while driving: compared to men, older women drivers report more difficulties in different traffic situations (Bishu et al., 1991; Rimmö & Hakamies-Blomqvist, 2002). Older women also experience several traffic situations more stressful than men do (Hakamies-Blomqvist & Wahlström, 1998; Hakamies-Blomqvist & Ukkonen, 1998) and have higher overall stress levels while driving (Simon & Corbett, 1996). The experienced stress might well be connected to risk perception and risk taking in traffic; women rate perceived risks higher in traffic situations (Caird & Hancock, 1994) and engage less often in less risk taking behaviours than men (Sivak et al, 1989b).

It has been suggested that older women are more insecure about their driving than men and that driving is more important to male identity (Burkhardt et al., 1996). Both arguments originate in the end in the cultural perceptions about driving and gender and in the different driving experience of women compared to men. How gender differences in driving habits will develop in the future remains to be seen. In order to avoid the "widow's gap" in mobility however, older women should be discouraged from relying exclusively on their spouses' driving for their personal mobility.

2.2.5 Consequences of older persons' driving habits for mobility, safety, and security

Older drivers' driving habits have consequences on their safety, mobility, and security. The effect on safety is likely to be positive, since they avoid traffic situations posing extra risks (such as bad road surface conditions, poor lightning conditions etc.). Their cautiousness as drivers also probably increases safety. However, in terms of mobility, risk-avoidance and negative self-bias can cause unnecessary mobility limitations if older drivers limit their driving because of lack of confidence and concerns about safety and security.

To understand the consequences of driving limitation and cessation for older road users, driving safety has to be compared with alternative modes of transportation. To give up driving often entails a switch to walking, biking and use of public transportation as the primary modes of transport. Walking and biking, however, are less safe modes of travel for older persons than driving (Hakamies-Blomqvist, 2003; OECD, 2001; Lamm et al., 1992). Public transportation in itself is safe but its use almost inevitable leads to an increased exposure as pedestrian. In most countries, older persons are overrepresented among pedestrian fatalities. As an example, a recent Australian study shows that although people aged 65 and older represent less than one-eighth of the Australian population, they have contributed about one-third of total pedestrian deaths in recent years (ATSB 2002).

Older women who tend to give up their driving at younger age and while still physically fit to drive (Sirén et al., 2004) risk to trade the relative safety of private car driving against the relative unsafety of increasing exposure as unprotected road users. The mobility consequences of driving cessation can be severe. Driving cessation limits mobility, increases dependency on other people, and has a detrimental effect on general well-being (Marottoli et al., 1997; Fonda et al., 2001; Burkhardt et al., 1996; Taylor & Tripodes, 2001; Peel et al., 2002). Driving cessation also tends to decrease experienced personal security related to travel (cf., Atkins, 1989; see previous paragraph on driving cessation). Premature driving cessation is a problem especially for women.

2.3 Older drivers' accidents

2.3.1 Are older drivers overrepresented in accidents?

In traffic safety forecasts, reference has often been made to older drivers' "overrepresentation" or "higher risk". As argued by Hauer (1988), such an argument is neither empirically nor logically convincing. It is not even of crucial importance for the planning of safety measures: from a cost-benefit point of view it is reasonable to design safety measure for the existing road user populations. As older drivers become an increasing proportion of all drivers, gains in safety benefits from measures targeted toward older drivers will also increase. For this conclusion to be valid, assumptions about their overrepresentation are not needed.

Figure 1 shows injury and fatality rates for drivers in different age groups in 1997 in the U.S. using different exposure measures, all of which are commonly used in accident studies, and all of which have certain validity problems.

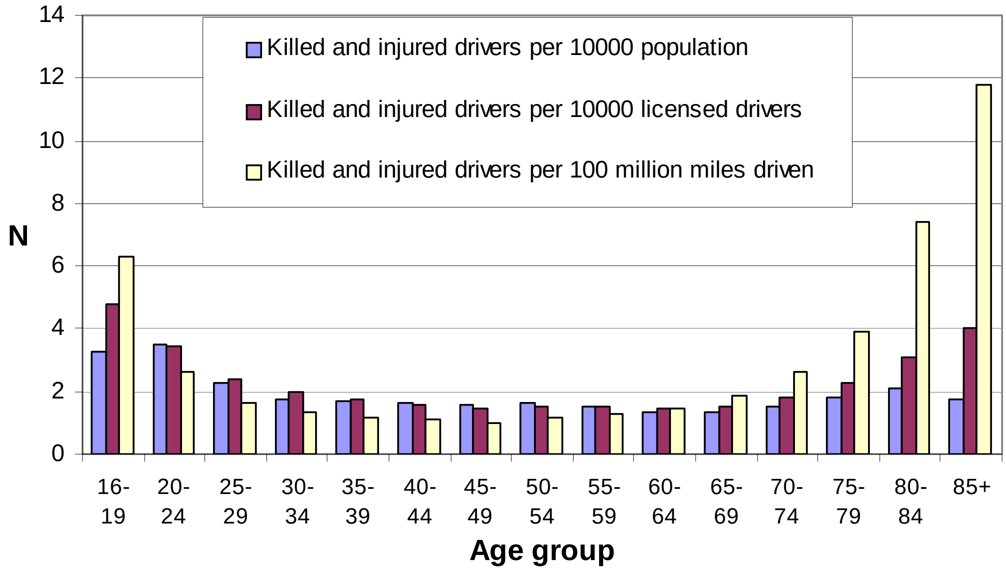


Figure 1 *Driver fatalities and injuries by age related to population, number of driver licenses, and mileage driven. Data from FARS the year of 1997.*

Read in a straightforward way, this figure seems to show that while age-related risk increase is modest when related to population or number of licensed drivers, there is a sharp age-related risk increase of accidents per mileage. Hence, one might conclude – as has often been done – that older drivers get more dangerous with age but compensate for this by driving less. Such an explanation, while not entirely erroneous, does not take into account certain methodological difficulties in interpreting the findings presented in the figure.

When used in comparisons between age groups, both terms of the equation Risk = Accidents/Exposure have certain validity problems, however measured. In most accident databases, cases are included on the basis of the consequences of the accident (such as "leading to personal injury"; "leading to fatality within vehicle"). For older drivers, this leads to a sampling bias called the “frailty bias”: a larger share of older drivers’ accidents get included in the official statistics because an old organism is more easily injured by a given physical impact. As demonstrated by Hauer (1988), a graph showing a marked increase in older drivers' fatality rates flattens considerably when fatalities are replaced by crashes of sufficient severity to kill 80-year-old-male drivers. According to Maycock (1997), half of the increased fatality risk of drivers aged 75 years or more, compared to drivers aged 30 years, might be due to the enhanced susceptibility of the older drivers to be killed in the accidents in which they are involved, i.e., to the frailty bias, rather than to their higher probability of incurring accidents. This sampling bias affects all the three measures presented in Figure 1, making the age-related risk increase to meet with an accident seem larger than it is.

The choice of different exposure measures results in different findings in age comparisons. In the late sixties and early seventies, it was accepted that the older drivers in the U.S. had less accidents per capita and per driver license, but more accidents per mileage than others (Planek, 1972). This finding has later been repeatedly replicated (see, e.g. Evans, 1991; Massie & Campbell, 1993). Accidents per population are a reasonable indicator of the general public safety impact of the accidents of a given age group. Because of different licensing rates in different age groups, however, the number of driver licenses provides a more accurate estimate of the number of drivers sharing the collective risk of any given age group. Unfortunately, not even this measure provides a valid basis for age comparisons, since the ratio of licensed drivers per active drivers may differ greatly between age groups, especially if different legal measures, such as health controls or driving tests, are applied at a certain age. Screening measures usually make it less plausible with increasing age for non-drivers to take the trouble of continuing to be licensed, which gives these age groups a worse accidents/license ratio. In addition, active driver groups of comparable sizes have in fact dissimilar exposure to accidents if their yearly mileages differ.

When discussing older driver risk in the sense of individual accident proneness or tendency, it is generally felt that a hard estimate of the actual amount of the driving, such as yearly mileage, is needed. In Figure 1, using mileage as the exposure measure, we do indeed get the U–shaped curve. However, it is important to notice that the relationship between yearly mileage and the number of accidents per mile is not linear. Those who have large yearly mileages always have fewer crashes per mile than those who have shorter yearly mileages (Janke, 1991). This has been found independently of age, gender and any other demographic characteristics. Therefore, a fair comparison of any driver group risk of accident per distance travelled should be made in groups matched for yearly mileage. Theoretically, this has been known for quite a while but only recently it has been demonstrated empirically (Hakamies-Blomqvist, Raitanen & O’Neill, 2002). In this study, drivers aged 65 and more were compared against a young middle age group of 26 to 40. Overall, the usual finding emerged: older drivers had somewhat more accidents per mile than younger ones, 10.8, against the younger groups, 8.3. However, when both age groups were divided in subgroups based on yearly exposure, corresponding to the 20-60-20 percentiles of the older group, and the age comparison was made in groups matched for yearly exposure, all the age disadvantage disappeared. If anything, the older drivers were safer. As a rule, in age group comparisons, older drivers have lower yearly mileages than other age groups – the older, the lower. Therefore, what in the U–shaped curve shows is not evidence for any age disadvantage in driver safety but simply a demonstration of the so called "low mileage bias".

In conclusion, none of the measures presented in Figure 1 permit straight-forward conclusions about how the drivers' individual risk of accidents increases with age.

2.3.2 Are older drivers a threat to other road users?

Contrarily to a common misconception, older drivers do not present an "excess" risk to other road users. They are mostly likely to be injured themselves in their accidents, both because of their greater physical frailty and because of the typical accident patterns (see below). As an example, when analysing the risk for other road users imposed by the driver group aged 65 and over compared to younger (<65) drivers, using Wisconsin Crash Outcomes Data for 1991, Dulisse (1997) found that for drivers aged 65–74, the associated risk per mileage was lower than for younger drivers, and for drivers 75+ the risk was slightly higher. However, all statistical differences disappeared after controlling for certain background variables. Maycock (1997) presents a similar conclusion on the basis of data from UK.

2.3.3 Typical accidents and attempts to explain them

Older drivers as a group have not only different accident rates but also qualitatively different accidents compared to younger drivers. A larger share of their accidents are collisions between vehicles, as opposed to single-vehicle accidents (Hakamies-Blomqvist, 1993; 1994b). They also tend to be legally responsible parties in their collisions (Cooper, 1990; Viano et al, 1990; Hakamies-Blomqvist, 1993); in the typical intersection accident situation (see below), they apparently do not notice the counterpart in time, and fail to give right-of-way. On the other hand, their small share of accidents as non-responsible parties also reflects the fact that they have a slow, conservative and cautious driving style, which makes them "harder to hit" as innocent parties than younger, less defensive drivers (for a detailed discussion of this issue, see Janke, 1991 or Hakamies-Blomqvist, 1998).

Of older drivers' collisions, a large portion occurs in intersections (Broughton, 1988; Fontaine & Gourlet, 1992; Hakamies-Blomqvist, 1994b; Hauer, 1988; Stamatiadis, Taylor & McKelvey, 1991). The typical situation is one where the older driver turns left against the oncoming traffic of the main road and is hit by a vehicle having right-of-way.

In research literature, age-related changes in accident patterns are often discussed in terms of "overrepresentation". This approach easily leads to what might be called the "proportional comparisons' fallacy"; i.e., a decrease in one accident type automatically leads to an increase in the share of the others, and vice versa. For older drivers, the increase in intersection accidents has been such a salient finding that less attention often is paid to the fact that older drivers are "underrepresented" in other types of accidents, such as single-vehicle accidents involving loss of control, or collisions due to speeding or risky overtaking. The decrease in accidents due to high speeds is, however, also a significant finding, since it corresponds well to what is known about changes in older drivers' driving habits.

The large share of accidents in intersections is often interpreted as a sign of older drivers' failing capacity of dealing with complex environments. Less often is their small share of off-the-road accidents seen as a sign of a mature, safety-oriented driving style. Without adopting such an ageistic perspective one might, however, pose the following question: since older drivers seem successful in avoiding accidents involving loss of control or judgment errors while overtaking, why are they not equally successful in avoiding accidents in complex environments such as intersections?

Two aspects of the task of merging traffic in intersections merit consideration. First, while older drivers' main strategy in facilitating the driving task is to decrease momentary load by driving slower, negotiating intersections is in many cases not a self-paced task but a forced-paced one, defined by the number of roads and lanes to be scanned and their respective free sight distances. Therefore, older drivers may be forced to perform under a time pressure that exceeds their capacity. Second, the task of driving in intersections accumulates a number of perceptual, attentional, and motor sub-tasks. To give an example regarding attention: the drivers have to divide their attention between different road directions to be scanned and vehicle handling, they have to select, focus attention to, and switch between the task-relevant aspects of the traffic situation, and they have to ignore irrelevant information. This is a complex task for anyone but increasingly so for older drivers, since all these attentional functions have been shown to deteriorate to some extent with age (for an overview, see Kausler, 1991).

In conclusion, intersection driving may become a "testing the limits" type of task, since it combines a host of age-sensitive functions while simultaneously limiting the usefulness of the normal safe driving strategy, i.e., that of driving slowly. However, as stated above, people age in different ways and their capacity to compensate for declines in single functions also varies. It would seem plausible that any individual risk increase be related to the combined deterioration pattern of a number of relevant perceptual and cognitive functions rather than to the deterioration levels of single functions. This idea gets support from research literature. Despite repeated efforts, correlations between single functions and accidents rates are at best low, and often only found in extreme subpopulations of older drivers (for an overview, see McKnight & McKnight, 1999). It may be relatively easy for an older driver with intact judgement to compensate for one single specific loss of function, such as moderate shrinkage of the visual field. In contrast, a simultaneous deterioration of several relevant functions probable poses greater demands on higher-level monitoring and compensating activities. Of course, if higher-level functions such as judgement are themselves impaired, one would expect a considerable risk increase. In addition, this line of reasoning not only applies to age-related performance changes but to any functional decrements.

2.3.4 Injury patterns and in-vehicle safety

Not only are older drivers more often injured and killed in accidents than younger ones, there are also some differences in injury patterns. Injuries involving rib and sternum fractures and chest complications are more common among older car occupants (OECD, 2001), whereas younger car occupants more often suffer from head injuries when involved in an injurious accident. To younger adults, rib fractures and other chest injuries are not usually life threatening but for older persons, they can pose serious risks. For example, for frail older persons, rib fractures can cause lung problems that require long-term rehabilitation and can sometimes cause the person's premature death (OECD, 2001).

Due to the seriousness of the consequences of older driver accidents, in-vehicle safety measures, such as airbags and seatbelts, become an important issue. The special needs of older car occupants are however important to note: for example, seatbelts designed for a body of a younger adult may cause even more damage to an older person in an accident situation. The in-vehicle safety measures will be discussed in more detail later on (see section "Design to protect the passenger", in chapter 4).

2.3.5 Gender differences in accident patterns

Roughly, the accident patterns of older women drivers are similar to those of older men. However, the accident characteristics typical to an older driver are pronounced in older women. The age-typical accident characteristics, e.g., increase in the proportion of intersection accidents and decrease in single-vehicle accidents, also emerge earlier than in men (Hakamies-Blomqvist, 1994a; Stamatiadis, 1996). The proportion of intersection accidents has been found to rise after the age of 55 for women, while for men the increase begins after the age 65 (Hakamies-Blomqvist, 1994a). Older women are more often at-fault in the accidents in which they are involved (Stamatiadis, 1996). Attentional problems as main cause of accidents get a dominant role in women already in the age group 45–54 and onwards, while in men the effect does not show in statistics until the age of 65 (Hakamies-Blomqvist, 1994a). In explaining such gender differences, the role of driving experience is important. It has been suggested that women's different accident patterns are due to quantitatively and qualitatively different driving experience (Hakamies-Blomqvist, 1994a). In any skilled performance, high level of expertise, in other words a large experience, is an effective buffer against the effects of age-related functional decline. This also applies for ageing and driving (Hakamies-Blomqvist, Mynttinen, Backman & Mikkonen, 1999). Therefore, gender differences among older drivers are likely to diminish as younger women driver cohorts with more extensive driving experience age as drivers.

2.3.6 Future changes in travel patterns, driving habits, and accident characteristics

In future, the older road user population will probably become more varied in terms of e.g., age, health, driving experience, driving style, and different social background factors. This is most likely to have an impact on older persons' travel patterns, driving habits, and accident characteristics. Four main changes will modify the future the older driver population. First, the number of older **women** drivers will increase significantly (e.g., Burkhardt & McGavock, 1999; Holland, 2001; Rosenbloom, 1995; Stutts & Martell, 1992). Second, there will be an increase in the number of **active** older drivers, i.e., those who have a long and active driving history and who continue to drive actively also in old age (see e.g., Burkhardt & McGavock, 1999). Third, there will be a gradual increase of the **oldest old** (80+) drivers (Burkhadt & McGavock, 1999; UK Department for transport, 2001b; see also Bilindustriföreningen, 1990; Bil Sweden, 2002). And fourth, there will be an increase of older drivers belonging to some **ethnic**

minority groups, at least in certain countries like the USA (Burkhardt & McGavock, 1999; Stutts & Martell, 1992; Pisarski, 2002).

The above-mentioned changes will cause increasing car driving among older persons. During the last decades, private car driving has already increased significantly among the older population both in North America (Rosenbloom, 1995; 2000) and Europe (Hjorthjol & Sagberg, 2000). It has been estimated that this increase will continue (Burkhadt & McGavock, 1999; UK Department for transport, 2001b). According to a report by the UK Department for Transportation (2001b), the greatest increase in driving is expected to be among older women and in the age groups 75–79 and 80–84. In a recent study, Foley, Heimovitz, Guralnik & Brock (2002) found drivers aged 70–74 years to be expected to continue driving for another 11 years. On the other hand, policies dedicated for mainstreaming the needs and requirements of different social groups, including older persons, have been increasingly taken into account when trying to develop functional public transportation (UK Department for Transport, 2001a). This kind of system-level development may influence the future travel patterns of older persons by making public transportation a more attractive mode of transportation, and consequently calming down the increase of private car driving.

The increase in the share of "actively ageing" (and driving) older persons among the elderly, the so-called citizens in third age, is reflected on the traffic behaviour of this population. The overall trip rate in the older population has shown slight increase during the last years, which is mainly due to cohort-related life style changes (Rosenbloom, 2000). This increase is likely to be related to increased car driving; the older Americans not only hold driver licenses more often than their European counterparts but they also use their cars more (Rosenbloom, 2000). Thus, trip rate increase in European populations is to be expected if the trends in private car driving follow the US ones.

The increase in active older drivers is likely to change the older persons' driving and travel habits so that they in general become more similar to those of the middle-aged. Increased driving may lead to changes also in attitudes and experiences while driving since, as Holland (1993) has found, driving experience is related to confidence in driving and self-bias in judgements.

In absolute numbers, the accidents and casualties of older drivers is bound to increase in future. This is however due to their increased exposure in traffic. Forecasts and concerns about the absolute accident increase in the future have been expressed by different actors (e.g., UK Department for Transport, 2001b).

Since the "typical" accidents of older drivers partly reflect the driving habits of the present older driver population, certain changes are to be expected in the accident characteristics of future older drivers with different driving habits. As the older driver population becomes more heterogeneous, even accident patterns are likely to vary more. When the baby-boomer generations reach old age, they are likely to bring with them their driving habits – and their accident characteristics. For example, older people's night driving and thereby their involvement in nighttime accidents may increase. On the other hand, older-driver typical accident characteristics are likely to emerge at an older age as younger cohorts age (Hakamies-Blomqvist & Henriksson, 1999).

Another important change that may have an impact in the accidents of older drivers is the increase of the oldest old drivers (80+). The oldest old drivers will have a greater likelihood of suffering from health conditions impairing functions important for driving and they also use more drugs than the younger old persons, which may affect their driving performance and safety (Burkhardt & McGavock, 1999).

There have been several efforts to forecast and predict what will happen with accident involvement trends as the populations' age (e.g. Bédard et al., 2001; Burkhardt & McGavock, 1999; Hakamies-Blomqvist & Henriksson, 1999; Stamatiadis & Deacon, 1998; Stutts & Marttell, 1992; UK Department for Transport, 2001b). All such studies agree upon the difficulties of these kinds of predictions. The potential future changes in older drivers' accidents are highly dependent on a multidimensional synthesis of demographic and system changes. Evans (2000) has even argued that the increase in the number of older drivers does not increase the safety risks in the traffic system.

The sources of uncertainty in safety projections do not only pertain to older drivers themselves; to their licensing rates, and travel and driving behaviour. It can also reasonably be expected that the transition of older drivers from a minority group with special needs and habits to one of the important subgroups of drivers will affect the dynamics of the whole system, including the behaviour of other road users. An occasional older woman driving slower than the speed limit may be a source of irritation for others, but there is little point in protesting against the diving style of, say, 30% of one's fellow drivers. The increasing probability of having to interact with an older driver may elicit profound changes in the behaviour of all drivers, as well as in the patterns of interaction among the participants of the traffic system. In a best-case scenario, this could have a calming effect on the whole traffic culture, thereby also reducing accidents.

2.4 Concluding remarks: Ageing and transportation as a public health issue

The topic of ageing and transportation, viewed as a public health issue, has two main dimensions: safety and mobility. Problems with both lead to adverse consequences for individual health and societal costs. In the past however, the focus has been largely on the safety aspect of this issue. This is not astonishing: accidents are relatively straightforward events both as to their public health consequences and as to their societal costs. Most industrialised countries indeed have their established systems for recording accidents and calculating the economic losses they cause.

In contrast, the relationship between mobility limitations and health loss is more complicated, and it is much more difficult to estimate the costs thereof. Figure 2 shows a conceptual graph of how mobility is related to health and health care cost outcomes (Hakamies-Blomqvist, 2000).

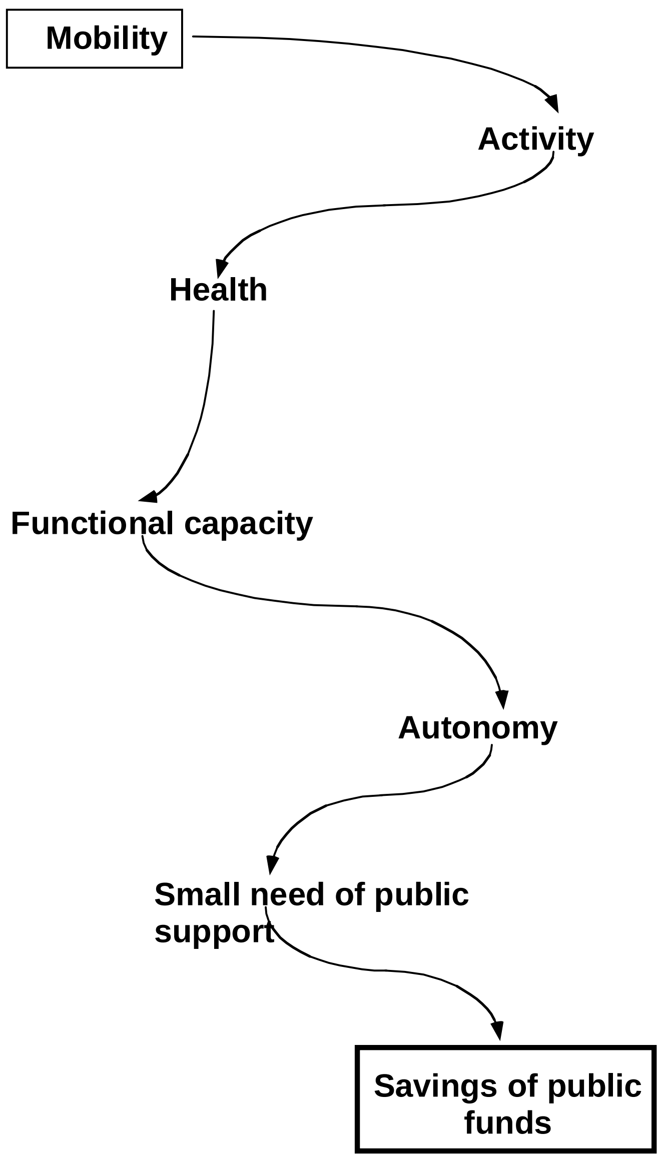


Figure 2 *A model of mobility, health, and societal costs in the elderly population.*

Briefly: it is necessary for an older person to live an active life and keep his or her former activity patterns; active elders are, statistically speaking, healthier elders than passive ones; health is directly related to functional capacity, and elders with good functional capacity are more able to lead autonomous lives and have smaller need for public support, which ultimately leads to savings of public funds. However, while all the links in this chain of reasoning have been substantiated empirically, an overall analysis of their economic impact still needs to be done. A thorough understanding of the economic significance of good outdoor mobility for ageing citizens would be very useful in guiding future policymakers' efforts towards sustainable policies within the area of ageing and transportation.

To summarise the public health view on ageing and transportation: an inadequate transport system threatens older citizens with two kinds of risk, or, in other words, of adverse health effects: those due to crashes and those due to lack of sufficient outdoor mobility. Thus, it is important to evaluate policies applied within the transportation sector in a wider social policy context. A single policy, action or measure may not always (and rarely does) have a single desired outcome, but rather may have both desired and non-desired outcomes and effects on several levels and areas of the social system. Sometimes it may also be necessary to balance against each others policy goals that, though all laudable, may be to some extent incompatible. To take one example: training older drivers may increase their confidence and enable them to increase their driving both quantitatively and qualitatively, thereby improving their overall mobility. However, on a general level, more exposure always implies more accidents. Within the Swedish philosophy of traffic safety work, the so-called Zero Vision, it is especially important to understand that all old people will eventually die, either in traffic or elsewhere. Given a long enough observation interval, mortality among humans is 100%. The fact that their increasing physical frailty increases their risk of being killed in traffic should not be used as an argument to exclude them or to limit their outdoor mobility, for fear to have them spoil the safety statistics.

3 Ageing and the driving task

3.1 Different dimensions of ageing

One of the major achievements of the twentieth century has been the mass ageing of populations in the industrialised countries. This achievement is comparable to (and partially due to) the reduction of child mortality from late Victorian times onwards. Despite the scale of this phenomenal success, it is not unusual to hear it described in gloomy or apocalyptic terms, such as the demographic time-bomb. It is as if the people of Chartres could only visualise their cathedral in terms of its maintenance costs. This terminology is revealing in that it demonstrates the pervasive influence of ageism, or discrimination on the basis of age.

Ageing is a complex and varied process, bringing at all ages a combination of growth and loss. The positive aspects of ageing are under-appreciated, although the added-value of the older worker is increasingly recognised. The literature on ageing and mobility could indeed benefit from a more robust emphasis on the beneficial aspects of ageing. These include wisdom, strategic thinking and less risk-taking. A striking proof of this is that those over 65, despite the highest prevalence of disabilities, which are postulated to be relevant to driving abilities, have the lowest crash rate per driver of any age group. More widely applied, these qualities could enhance mobility and safety for all age groups.

Ageing, in the sense of senescence, also implies a progressive loss of operational adaptability as time passes. Separation of the ageing process from age-related disease processes can be difficult. Many aspects of later life, which were once considered to be intrinsic to normal ageing, seem to have a basis in environmental exposure or disease: examples of this include hearing loss and visual impairment.

A significant feature of ageing is the emergence of increased inter-individual variability. The distribution of physiological variables around the mean is augmented and this has important consequences for public policy in many spheres. Not least of these is the need for a greater range of responses to life situations in later life: one size will not fit all. Generalisations become increasingly difficult to apply, particularly in terms of performance. Facilitating this level of flexibility in policy and practice will be one of the greatest challenges to coming generations.

Even though individual differences are highlighted in later life, regularities in the process of ageing can be described. There are normative models of changes on various dimensions, and a large body of knowledge about how age-related chances appear *typically* and *on average* in an ageing population. These changes can roughly be divided into social, psychological, and physiological/ biological. All these dimensions have relevance for the issue of ageing and driving, although most attention has been traditionally paid to biological and physical changes, and to cognitive and psychomotor performance within the psychological dimension.

3.1.1 Social ageing

Social changes related to ageing can be viewed on individual, interpersonal and societal levels. On the individual level, areas subjected to change include personal roles and attitudes (for early foundational theories see e.g. Cumming & Henry, 1961; Atchley, 1971). With increasing age, social roles usually change or are in transition; e.g. from parent to grandparent, from employee to retiree, and from married person to a widower. As the personal roles change, the relationship to one's social context also changes which in turn may trigger changes in attitudes and values.

On the interpersonal level many areas also undergo changes in older age. Changes in social surroundings and thus in social ties are common, as the person often transitions from, e.g., employee to retiree. Also the probability of loosing one's spouse or close friends increases in later life. These kinds of changes are major, and often dramatic in the individual's life. They often, but not always, imply losses. However, earlier relationships may have not always been satisfactory, and giving up of them may also be emancipating (e.g. Öberg & Ruth, 1994; see also Carr et al., 2000). Age-related social changes are highly relevant to the issues of older drivers. First, the social changes in later adulthood have their direct effects on travel behaviour and needs. Second, it is important to understand complex interactive effects: for example, the common tendency of older women to give up their driver license at younger age and in rather good health (Hakamies-Blomqvist & Wahlström, 1998; Sirén et al., 2004) combined with loss of spouse or narrowing of the social network can have very negative outcomes in terms of well-being and mobility.

On a societal level, certain trends can be observed. A majority of older people age in place, although a small minority migrate, particularly in the USA. About 70 per cent of people aged 60 years and over in developed countries live in urban areas: this trend is likely to become more pronounced in the future. Rural areas have particular features: the flight of the young to urban areas alters the proportions of the remaining population. Although in certain areas concentrations of affluent older people can be fiscally beneficial and older people in rural areas are more likely to be involved in community and voluntary activities, the provision of an appropriate health, social and transportation infrastructure can be difficult. Men also outnumber women in many older rural populations, the reverse of the norm in urban/suburban areas.

Marital status differs by sex: currently, men are more likely to be married, while older women are more likely to be widowed or single. The number of divorced or separated older people is small but rising. These patterns are likely to alter in the future with future generations more likely to enter old age without enduring marital ties and fewer children. Increasing numbers of older people live alone, ranging from 14% in Japan to 49% in Sweden. Over the last few decades, most developed countries have experienced large increases in the number of older people who have been institutionalised but there is evidence that this trend is slowing down. An OECD study showed no change in rate of institutionalisation among seven of eight countries between the 1980's and 1990's. Home support programmes are most developed in the Scandinavian countries, with 12–24% of elderly people receiving home help care.

Although there is great diversity among older people in terms of income, several trends are noticeable. There is a fall in income after retirement. In the US and Scandinavian countries, this decrement is moderate, but is much more marked in other developed countries. Certain populations will be more vulnerable. Older women are poorer than elderly people in general and elderly women living alone are the poorest of elderly people. This stems in part from lower income and more extenuated pension provisions. This will affect their ability to sustain self-funded mobility options such as driving, change of domicile or taxi use.

In developed countries without strong advocacy for older people, it is not unusual to find deeply ingrained ageism in legislature as well as health and social provisions. Standards for health and social care for older people often fall short of that offered to their younger peers. The phrasing of the mobility debate in terms of increased risk rather than reduced mobility is a classical example of this discrimination.

3.1.2 Psychological ageing

Psychological ageing contains several factors, such as cognitive functioning, psychomotor performance, and personality. Research has pointed out certain age-related changes in cognitive functioning and psychomotor performance that are of interest in traffic research. For example, psychomotor performance gets slower (see e.g. Gogging & Stelmach, 1990), sensitivity to certain stimuli decreases (see e.g. Hoyer, 1990), and dividing attention between several tasks becomes more difficult in complex tasks, such as car driving (e.g. Brouwer, Waterink, Wolffelaar & Rothengatter, 1991). The issues of driving and psychological ageing in terms of cognitive and psychomotor performance will be reviewed and discussed more closely further on.

In terms of personality, several theorists have attempted to capture and describe systematically the typical psychological changes and development during the life span. To give some examples, Erikson (see e.g. 1980) who introduced his model of psychosocial developmental stages, and Bühler (1933, cited in Sugarman, 1996) with the concept of life tendencies, have contributed to the field of psychology of aging. Both of these theories emphasise the life span's periodical nature, that is, that a person lives through different stages during her/his life. A more recent approach, called process approach (e.g. Cutrona, Russell & Rose, 1986; Hultsch & Plemons, 1979; Thomae, 1980), emphasises the role of various factors, such as self-concept, other personality processes, and social support in the adaptation into older age. All major theoretical approaches to personality in old age, and especially those of process approach, emphasise the role of personality in coping with age-related changes; be they social or biological/ physical. Psychological ageing in terms of personality is of relevance for transportation issues when for example trying to understand how people cope with after driving cessation or in other types of situations implying mobility (see e.g. Bonnel, 1999; Eisenhandler, 1990; Marottoli et al., 1997). Personality characteristics in form of, e.g., decision-making style or adjustment to stress can also play a part when trying to understand the driving behaviour of older drivers (see Holland, 2001).

3.1.3 Physical ageing

Age-related biological and physical changes include bodily changes, e.g., changes in blood circulation systems, sensory systems, immune system, body mass, and muscles. Many of these changes affect the individual's capacity to function, and some of them predispose the individual to illnesses.

However, it is important to understand that social and biological factors have a very strong relationship influencing the process of ageing. This has been described most concisely in the domain of Health-Related Quality of Life. Indeed, some social attributes also represent biological groupings, such as age and sex. Many social strata are derived from biological strata and the integration of health and social strata remains a challenge and a priority to researchers and service providers. Social attributes such as age cohort, sex, education, socio-economic and ethnic status are important determinants of health and functional status but also in behaviour such as seeking and accessing healthcare and social supports. These factors impact on the self-care and disparities among these groups may be widening. Educational disparities in standardised mortality ratios have increased by 20% in women and 100% in men between 1960 and 1986 (Pappas et al., 1993). This relationship is not only important in preventing chronic disease but also in preventing its deterioration. Therefore the maintenance of functional well-being must take into consideration social factors: these will also have direct relevance to mobility.

Attempts have been made in gerontological literature to define the nature of age-related changes more precisely in categorising them as pathological versus normal. It is, however, difficult to draw the line between the two and keep them as "neutral categories", as the former holds a distinctly negative label. The heterogeneity of older populations also causes difficulties in categorisation. In general, the likelihood of having functional disabilities and illnesses becomes more marked after the age of 75.

The WHO has proposed a model of health transition which distinguishes between total survival, disability-free survival and survival without disabling chronic illness. It is becoming relatively clear that in nearly all developed countries disability-free life expectancy is increasing. This has been shown in the UK and the USA. Using data from the 1982, 1984, 1989 and 1994 rounds of the US National Long Term Care Survey, studies have shown a decline in the disability rate of older US citizens of 1.3% per year. This has resulting in 1.2 million fewer disabled people in 1994 than would have occurred if the rate had not declined.

Since physical ageing often is referred to as the most important dimension of ageing when dealing with issues like driving ability and safe driving, we will return to the average age-related functional changes on a physical level further in this report, attempting to relate them to the demands posed by the driving task.

3.2 Driving as skilled performance

3.2.1 A conceptual model of driving

Driving has traditionally been conceptualised as a complex information processing task with dynamic interaction between the driver and traffic system. More recently, the understanding of the driving task has deepened in two senses. First, driving has increasingly been understood as a process that requires, involves and depends on cognitive processes that include basic functioning but also goal setting, planning and other higher behavioural patterns (see Groeger, 2000). Second, emphasis on driving as a skilled performance has overcome the limitations implied by the ahistorical nature of the earlier information processing models.

Most recent work on driver behaviour models, e.g., Groeger (2000) and Fuller (2000), has been strongly influenced by the work of Michon (1985), who suggested the driving task to have a hierarchical structure. Michon's model consists of three levels: a strategic level, a tactical level, and an operational level. The strategic level is responsible for general plans, including route planning and route choice, and it sets criteria for lower level functions, such as speed control. The tactical level is responsible for controlled action patterns, including various interactions with the traffic situations. The operational level is responsible for automatised action patterns, including basic driving controlling processes. A similar model was however proposed as early as in 1971 by Allen et al., who labelled their corresponding levels as “navigation”, “guidance”, and “control”.

Recently, a fourth level, motivational models, has been suggested as a complement to Michon’s hierarchical three-level model (see Hatakka, Keskinen, Gregersen & Glad, 1999). The GADGET model has been used in several context, recently within the EU project AGILE (Breker et al., 2003). It complements the original hierarchical model with further individual and social factors of relevance to the driving task, such as risk-acceptance, peer group norms, and attitudes (see Table 2.).

***Table 2** The GADGET-matrix (adapted from Hatakka et al., 1999).*

Hierarchical Levels of Driver Behaviour		Knowledge and Skills	Risk-Increasing Factors	Self-Assessment
	4 Goals for Life and Skills for Living	**Awareness about relation between personal tendencies and driving skills** • lifestyle/life situation • peer group norms • motives • personal values • …	**Risky tendencies like** • acceptance of risks • high level of sensation seeking • complying to social pressure • use of alcohol and drugs • …	**Awareness of** • impulse control • risky tendencies • dangerous motives • risky habits • …
	3 Driving Goals and Context	**Awareness about** • effects of journey goals • planning and choosing routes • effects of social pressure by passengers inside the car • …	**Risks associated with** • physical condition (fitness, arousal, alcohol, etc.) • purpose of driving • driving environment (rural/urban/higway) • social context and company • …	**Awareness of** • personal planning skills • typical driving goals • alternative transport modes • …
	2 Mastery of Traffic Situations	**Knowledge about** • traffic regulations • traffic signs • anticipation • communication • safety margins • …	**Risks associated with** • wrong expectations • vulnerable road-users • violations • information overload • unusual conditions • inexperience • …	**Awareness of** • strong and weak points of manoeuvring skills • subjective risk level • subjective safety margins • …
	1 Vehicle Manoeuvring	**Skills concerning** • control of direction and position • vehicle properties • physical phenomena • …	**Risks associated with** • insufficient skills • environmental conditions (weather, friction etc.) • car condition (tyres, engine etc.) • …	**Awareness of** • strong and weak points of car control skills • …

As driving is understood as a complex skilled performance, it becomes evident that the number of factors contributing to the successful execution of this task is very large. Since these factors are not only physiological or cognitive in nature, but also psycho-social and social (Groeger, 2000; Hatakka et al., 1999), the preconditions for safe driving are not easy to define in a comprehensive manner. In addition, these factors work in interaction with each other, which, in the end, enables for example various compensatory measures in driving (Fuller, 2000). In the case of older drivers, this kind of constructivist concept of driving is advantageous in many ways: it helps to understand the relation between ageing and driving ability in its complexity, makes sense of the importance of different compensations strategies, and has useful implications to both older driver training and assessment (c.f., Breker et al., 2003). In the following, these implications are presented more in detail.

3.2.2 The implications of a constructivist approach on driving

The consequences of the comprehension of the driving task as a complex every-day skilled performance are important. The new understanding of the nature of driving has implications for driver assessment, driver training, as well as for infrastructure design.

First, as it comes to driver assessments, it is clear that driving competence cannot be assessed by assessing single contributing factors, though there is a persistent flow of studies attempting to identify single factors that may contribute to elevated accident risk. A recent report published by the British Psychological Society (2001) however strongly advises for a multi-disciplinary and thorough procedure in fitness-to-drive assessments. In the ongoing AGILE project, (Breker et al., 2003), suggestions for older driver assessment have been based on the GADGET-matrix by Hatakka et al. (1999).

Driver training faces new challenges when a constructivist approach is adopted. Hatakka et al. (1999) discuss best practices of driver training (though focusing mainly on novice drivers) within a theoretical framework of constructivist driving behaviour models. They suggest more coverage on social and psychological aspects and self-evaluative skills in driver training. Improvement and development of self-evaluative skills in training are of importance for older driver training (c.f., Breker et al., 2003; Eby, Shope, Molnar, Vivoda & Fordyce, 2000). The emergence of different older driver training curricula can be seen as reflecting the growing understanding of the constructivist nature of the driving task and driving ability.

A thorough conceptual understanding of the construction of the driving task also has some implications for infrastructure design, including road and vehicle design. In road design, measures targeting the different hierarchical levels of driving behaviour can be used. Applying the hierarchical thinking of Michon and his predecessors, such measures can target (1) the operational level regarding very low-level feedback from the environment (such as the vibration feedback from road surfaces to the driver), or (2) the tactical level regarding higher-level feedback from the environment (such as road signs or sight distances), or (3) the strategic level, regarding design features relevant for trip planning, such as route guidance. Road design features mostly have relevance for the tactical and operational levels. Vehicle design is more applicable on all of the hierarchical levels, since it can affect higher-level functions such as trip planning and also motivational aspects by affecting the driver's subjective feelings in the performance situation (e.g., design to make driving physically more comfortable).

However, a critical note is needed here. The usefulness for design purposes of modern theories of driver behaviour is rather limited, applying mainly to single features of the road infrastructure and vehicles. Yet, a well designed road infrastructure is much more than the sum of its individual elements. In search of a more "holistic" guidance for good infrastructure design from useful theories of how humans operate, one is tempted to go all the way back to the work of the early Gestalt Psychologists and to James J Gibson (1904–1979) and his concept of *affordance*, capturing the way in which the visual environment offers to the animal acting in it information about possible relationships between the actor and the environment (Gibson, 1979). Within the field of perceptual theories, little of value for the design of good configurations in road infrastructure seems to have happened since these classics.

3.3 Functional age-related changes and the driving task

Here we will briefly go through the physical age-related functional changes that are considered most important for the ability to drive. We will describe changes in visual function, spatial and motor abilities, cognitive performance, and illnesses (including common illnesses and dementias) as they are related to driver performance and the driving task.

3.3.1 Visual function

Visual function in a driving context usually refers to visual acuity, vulnerability to glare, and contrast sensitivity. Sometimes attention, measured with instruments like the UFOV (useful field of view, see Ball, Roenker & Bruni, 1990), and perception are viewed as part of visual function but in this review they will be discussed as cognitive functions.

Static visual acuity, that is, ability to observe details, has been found to decline by age (Corso, 1981). Changes in the eye (the lens and muscular control of the lens) cause changes in accommodation ability, which can be detected as problems in focusing on near objects. Changes on retina (reduction in the number of receptor cells) also cause changes in perceiving details in the visual field. Dynamic visual acuity, that is, ability to observe moving objects, also has been found to decline with age (Ball & Sekuler, 1986; Burg, 1966). Visual acuity can be improved by suitably increasing illumination (Holland, 2001), and thus improving the lightning conditions on the road could solve some of the problems that older drivers may experience in terms of visual acuity. It is however unlikely that this would work as a traffic safety measure, since visual acuity has not been found to be related to accidents in older drivers (Holland, 2001; Wood, 2002). It might however be successful in terms of mobility, as a measure for promoting more comfortable driving for older drivers.

Opacity of the lens can increase the risk of glare. This is a problem related to increasing age though as a serious problem it mainly pertains those with cataracts. Glare combined with bad road-surface conditions has been found to cause problems in perceiving the road markings for older drivers (Holland, 2001). Problems of glare are related to poor illumination and road-surface conditions, and thus could be eased with proper road design (Staplin, Lococo & Byington, 1998). Owsley et al. (2002) also note that for those elderly suffering from cataract, going through a surgery seems to have a significant positive impact on driving ability.

Age-related decrease in contrast sensitivity can cause problems for older drivers with perceiving traffic signs (see Owsley & Sloane, 1987). There are a number of studies about the visibility and legibility of different design types of signs (for a review, see Holland, 2001). For older drivers especially, larger text and larger and more symbolic signs (in contrast to those with text) would be easier to perceive and understand. Contrast sensitivity impairments have shown a more significant association with increased crash risk than other visual function impairments (Owsley et al., 2001).

3.3.2 Cognitive function

Visual function has effects on the probability of making perceptual errors while driving, for example, errors in assessing the velocity of oncoming vehicles, and thus ultimately, assessing risks. Compared to younger drivers, older drivers have been found to overestimate the speeds of other vehicles at lower speeds and to underestimate them at higher speeds (Scialfa et al., 1991). However, this feature has been shown not to be reflected on increased accident risk (see Schiff, Oldak & Shah, 1992; Wolffelaar, Rothengatter & Brouver, 1991).

The effects of changes in visual function on perception and attention have been demonstrated with studies on useful field of view (UFOV) (e.g., Owsley et al., 1991). Useful field of view refers to a dynamic measure of the functionally available field of view – an area of the visual field in which visual information can be collected without eye or head movements. UFOV is a measure of attention and it has been found to be somewhat useful in predicting accidents, especially when combined with a measure of cognitive performance (Owsley et al., 1991).

Attention as a cognitive function (studied also by other means than the UFOV) is of course highly relevant for the issue of ageing and driving. The driving task requires division of attention between several sub-tasks, especially in more complex traffic situations like intersections. Older persons have been found to perform poorer than their younger counterparts in dual-task experiments (see Brouwer et al., 1991; Crook, West & Larrabee, 1993) and also to have more difficulties in filtering out the irrelevant stimuli (Rabbitt, 1964). Findings related to attention and ageing may partly explain the problems older drivers experience in intersections and other complex traffic situations. However, many of the experimental settings are vulnerable in terms if ecological validity (Hakamies-Blomqvist, 1994b).

Reaction times increase with age (see Cerella, 1985), which is partly related to the age-related changes reflected in attention. As the number of information sources that need to be reacted upon increase, reaction times increase (Rabbitt, 1985). Generally speaking, reaction times to simple stimuli do not deteriorate dramatically with age (Olson & Sivak, 1986); rather, increase in reaction times among older drivers is shown in the slowing down of making decisions in complex situations (Quimby & Watts, 1981).

There have been attempts to understand the components responsible for the increase in reaction times. Stelmach and Nahom (1992) have subdivided the period between stimulus presentation and response initiation into four components: response preparation, response selection, response programming, and response complexity. As regards response preparation, older adults need more time to decide on the appropriate response given the available information (stimuli). Suggestions for the placement of road signs directly relate to these findings. Given that older adults benefit more from longer exposure to stimuli, Winter (1985) proposed that signs should be spaced farther apart to allow drivers enough time to view information and decide what action to take. Multiple-response alternatives lead to a further deceleration of the perception-reaction time of the older person (response selection). Although reaction times of younger drivers also are slower as the number of response alternatives increase, older drivers' reaction times increase even more. Stelmach & Mahon (1992) suspect that response selection is the most age sensitive of the four facets of response initiation. Once a certain action has been chosen, older persons have greater difficulty altering the planned action (response programming). Response execution – the actual reaction – further slows reaction time as task complexity increases (response complexity), not because of the mere complexity of the task but because of the initiation of the task. Task experience can reduce this effect.

3.3.3 Motor abilities

Motor performance also slows down with age. This is partly due to general age-related joint and muscle stiffness and muscle power and mass reduction, but also partly due to cognitive changes that have the same origin as changes in attention and reaction times described above.

Motor performance in tasks requiring attention and reaction time, is likely to become more challenging, as the situation gets more complex. There is a slowing down in all the facets of movement initiation and movement execution (Salthouse, 1985; 1989; Stelmach & Nahom, 1992), which combined with a complex task slows down discrete movements. The organisation of movement sequences also has been suggested to become more time consuming. In one study, older drivers have been found to be more serial than younger drivers in the organisation of their car control operations (Hakamies-Blomqvis et al., 1999).

Age-related changes in joint and muscle flexibility, muscle power and mass can affect driving performance, or the way driving is experienced. They can influence the ability to get in and out of a car, operate the vehicle, and can influence injury and recovery (Sivak et al., 1995) for drivers involved in accidents. Restriction of head movements can affect the easily accessible field of view (Isler, Parsonson & Hansson, 1997). Furthermore, limitations of neck motion range may come into play while checking for oncoming traffic at intersections or before merging.

3.3.4 Age-related illnesses affecting driving

Most common age-related illnesses include arthritis (including also milder pain in joints), heart diseases, arterial hypertension, and diabetes (WHO, 1998). Arthritis and pain in joints can make driving as well as other forms of transportation difficult or unpleasant (see e.g., Roberts & Roberts, 1993; States, 1985). However, there are not many empirical studies about their possible effects on safe driving (for a thorough review, see Janke, 1994a). Those disabilities and illnesses that affect physical mobility are however highly relevant when discussing older persons and transportation, since they are not only very common, but may also seriously limit older persons' modal choices (see Sirén et al., in press).

Heart diseases, that is, coronary heart disease, angina pectoris, and myocardial infarction, usually affect driving performance only momentarily (that is, at the moment of the seizure). They pose certain risk for traffic safety (see Janke, 1994a) but there is no evident safety countermeasure since seizures are difficult to predict and to prevent. They have however been found to affect driving habits: after a hospitalisation for heart disease driving tends to decrease and eventually mobility is reduced (Waller, 1987).

Diabetes and driving has been a largely studied area (Janke, 1994a) but there is no consensus on if, and how, diabetes affects driving ability. More recent research seems to suggest however that diabetes patients do not have elevated risk for traffic accidents unless the disease is severe (McGwin, Sims, Pulley & Roseman, 1999). Fluctuations in blood sugar level affect cognitive functioning and therefore success as driver may depend on how effectively the given treatment can stabilise the driver's blood sugar level.

3.3.5 Dementia

There are various estimates on the prevalence of dementia. Some claim that of the population aged 65+, ca. 15% have dementia of some type to some degree (Barclay et al., 1988). According to a Finnish study, the proportion of persons suffering from dementia in the population aged 65–74 is much smaller (ca. 4%) than in the population aged 75–84 (ca. 11%) or 85+ (ca. 17%) (Erkinjuntti, 1988). The majority of dementias are attributable to Alzheimer's disease (Barclay et al., 1988; Erkinjuntti, 1988).

Dementias in general cause impairments in cognitive abilities and judgement skills (Janke, 1994a) that can manifest themselves as difficulties in driving. Dementias are degenerative diseases, but depending on the type of dementia, the effects on driving ability can take 1–10 years to become apparent (see Janke, 1994a). Thus, in the early stages of dementia, the driver usually is able to normally operate an automobile (see Lundberg et al., 1997).

Cognitive impairment and dementia are associated with driving difficulty, driving reduction, and driving cessation (e.g., Freund & Szinovacz, 2002; Foley et al., 2000; Stutts, 1998). Dementias at more progressed stages will eventually impair the ability to operate the car (see The British Psychological Society, 2001; Janke, 1994a). The impact of demented drivers on traffic safety on a general level is however difficult to estimate. The accident risk of drivers suffering from dementia has been estimated to be higher than the risk of healthy older drivers (e.g., Carr, Jackson & Alquire, 1990; Drachman & Swearer, 1993; Dubinsky, Williamson, Gray & Glatt, 1992; Fitten et al., 1995; Friedland et al., 1988; Lucas-Blaustein, Filipp, Dungan & Tune, 1988), but as the estimation of accident risk itself may be to be biased, as noted earlier, these findings are hard to evaluate. In addition, the fact that dementia and related impairments tend to lead to a reduction of driving exposure suggests that the overall exposure of impaired drivers is minor – thus creating a very modest problem for traffic safety in general. There are studies suggesting that only 20–30% of drivers with dementia actually continue driving (Carr et al., 1990; Gilley et al., 1991; Logsdon, Teri & Larson, 1992; see also Foley et al., 2000). In a Swedish-Finnish collaborative study, Johansson et al. (1997) addressed the question of how big a share of all older drivers' accidents actually could be attributable to drivers suffering from dementia. They used micropathological methods to study certain parts of the brains of aged drivers killed in traffic accidents, and concluded that those with neuropathological changes in their brains, indicating possible or probable DAT (dementia of Alzheimer type), were clearly overrepresented, around 50% of the killed drivers. More research is however needed to substantiate conclusions about the overall effect of demented drivers on general traffic safety. For a thorough and detailed presentation of the issue of driving and cognitive decline, see Lundberg (2003).

4 Safety measures targeted to older drivers

4.1 Restrictive policies

4.1.1 Are there risky drivers?

The aim of any safety measures is to enhance safety of certain or all road user groups or traffic environments. The most commonly discussed safety measure related to older drivers has been, up to date, restriction of driving, mainly by identifying and excluding from the wheel those who are "too risky" to drive.

And how shall we know which drivers are "too risky"? There is a growing body of research literature trying to relate single functions to driving safety or fitness. Most of these studies suffer from severe methodological and conceptual weaknesses. In the following, we shall discuss some key issues.

First, the idea of identifying single functions predicting driver safety or lack of it is not theoretically well-grounded. Given the complex nature of the driving skill, as described above, deficits in almost any single function can be compensated for, at least on lower cognitive levels such as vision, general slowing, or motor limitations. Indeed, it has been claimed that research should aim at finding patterns of deficits rather than single deficits that are crucial for driver safety (McKnight & McKnight, 1999). In addition, as a basis for exclusion from traffic, we need indices that are predictive for safety. We have no ethical or scientific grounds to exclude from driving "bad" drivers or "clumsy" drivers or any defective drivers except for those who have a higher risk of accident. Hence, any diagnostic criterion should ultimately be validated against accidents. This is however difficult to achieve, given that accidents are, on the individual level, a rare and multidetermined event (Hakamies-Blomqvist, 1994b; Hakamies-Blomqvist, Henriksson & Heikkinen, 1999).

Second, "too risky" is not a scientific concept. It is questionable whether there is such a thing as individual driver risk that could be individually measured or estimated and used as a criterion for decisions about driving. Risk of accident at any given moment is a complex sum of a number of factors whereby the individual's earlier decisions regarding driving also play a role. Thus, higher level of strategic skills, leading to wise decisions about when, where, and how to drive, may be more important than good physiological functions or operational skills – and yet more difficult to measure. If driving is conceptualised according to the constructivist model, it also follows that a "safe-enough" driver can be constituted in many different ways. Younger drivers may succeed in safe driving despite risk-taking and high speeds, because of their superior motor abilities and rapid reactions, whereas older drivers may drive safely despite their declining perceptual and attentional functions grace to their wise strategic decisions and generally safety-related attitudes.

Third, even supposing that we could reliably measure individual driver risk, there is no scientific way to determine who is fit to drive and who is not. Decisions about acceptable level of risk are always political in nature, and should optimally be taken within the realm of a balanced societal discussion taking into account different competing values, e.g., weighing the societal losses attributable to the unlikely event of an accident against to the certain losses in quality of life following non-voluntary exclusion from driving.

Despite lack of positive evidence regarding positive safety effects of older drivers screening, there exist varying practices in different countries to identify risky and unfit drivers and restrict their driving (e.g., OECD, 2001; White & O'Neill, 2000). All such policies include some form of driver assessment or fit-to-drive screening. In the following, assessment of older drivers in general and screening as a safety measure are described and discussed in more detail.

4.1.2 Screening of older drivers: A Jack-in-the-box safety measure

Based on the generally accepted albeit erroneous idea of older drivers as a high-risk group, age-related screening often is suggested as an effective safety measure. The general idea would be to regularly "check" license holders after a certain age in order to exclude from the driver population those with increased accident risk. This idea, jumping up again and again like a Jack-in-the-box, has support from many directions. Not only has it some (simplistic) face validity but it also creates visions of wonderful business opportunities. In the ageing Europe, the professions vested with the screening tasks would get numerous new working opportunities and anybody inventing a testing gimmick for driver risk and getting it included into a pan-European standard equipment would greatly increase his/her personal wealth.

However, all serious studies that have aimed to evaluate the safety effects of general age-based driver screening have failed to show any benefits (for an overview, see OECD, 2001). There are many reasons for this. While certain older drivers undoubtedly have higher risk of accident than others, and in some cases for age-related reasons (such as dementing illnesses whose incidence grows with age), it is difficult to find correlations between single functional measures and risk, and even the most carefully done studies relating functional measures to accident risk end up with correlations so low that they cannot be used as decision criteria. In addition, on the individual level, accidents are rare events. In Sweden, one in 20,000 drivers yearly is involved in a personal injury accident. Hence, if we have a "high-risk" group with twice the average risk, still only one in 10,000 drivers yearly is involved in such accidents. To prevent one personal injury accident per year by excluding this "high-risk" group from driving, provided that we could perfectly identify its members (which we normally cannot), therefore would cost the mobility of 9,999 drivers who would not have had accidents. In addition, these 9,999 drivers probably would switch to other, less safe modes of travel and we might well end up by having decreased their overall safety. What this example illustrates is that driver diagnostics and screening only can produce safety effects and be cost effective if targeted on sub-groups of drivers who have identifiable and very high risk increase, such as drivers with diagnosed dementia, not on the level of the general population.

There are some studies evaluating the effectiveness of screening (Hakamies-Blomqvist et al., 1996; Kelsey, Janke, Peck & Ratz, 1985; Zaidel & Hocherman, 1986). Hakamies-Blomqvist et al. (1996) evaluated the safety effect of medical screening in Finland by comparing Finland (where there is screening in connection with license renewal at the age of 70) and Sweden (where no screening practices are used). They found no safety effect resulting from the Finnish screening system. On the contrary, the screening practice resulted in part of the drivers beginning to travel as unprotected road users, thus being more exposed to safety risks. There is previous research evidence that screening practices also tend to make certain subgroups of fit-to-drive drivers – especially women – to stop driving (Sirén et al., in press); thus, it can be seen as a measure with wide negative outcomes on a system level.

4.2 Supportive actions

4.2.1 Older driver training and rehabilitation

As the importance of independent mobility for older persons has been recognised and the complex nature of the driving ability and the driving task has become better understood, increasing number of interventions of more supportive nature have emerged. These include older driver training and re-training, and rehabilitation of drivers whose driving ability has decreased due to some health-related deficits. Such activities often have a double goal of ameliorating both mobility and safety. The increase in different older driver training courses and educational resources reflects the growing knowledge about driving experiences positive impact on e.g. compensatory skills in driving (see e.g. De Raedt & Ponjaert-Kristoffersen, 2000).

Most industrialised countries have at least some form of older driver training. These courses and programmes are usually rather young, established in the 1990's, and there is no published systematic evaluation research. In a report by the EU-funded AGILE project, however, there is in-detail documentation on the Belgian older driver training, as well as brief but comprehensive descriptions on the older driver training measures and programmes in the US and UK (Breker et al., 2003). A study by Janke (1994b) tried to evaluate the outcomes of older driver training programme in California, though the results were somewhat ambiguous. Some preliminary results on the validation of a self-evaluation tool also have been published (Eby et al., 2000).

There is great variation in courses and educational and rehabilitation resources in different countries. There are self-study materials of varying degrees, in-class studying, and practical training. The most common issues included in different courses and educational materials/resources are health and driving, sensory abilities and driving, medication and its impacts on driving, exercise for keeping up physical mobility, and driving cessation (Breker et al., 2003). The reported experiences of the users (older drivers) have been positive (Breker et al., 2003; Eby et al., 2000). Older driver training in Europe is usually arranged and/or sponsored by state or governmental organisations, whereas in the US other organisations (both profitable and non-profitable) also are involved. Some programmes are realised in collaboration with insurance companies, so that those participating in a re-training course get discounts on the insurance fees (see Janke, 1994b).

A lot of bench-marking still remains to do as to the best practices of older driver training, and there are certain complex questions to be considered, such as, on whom the training resources should be directed to, i.e., how the target groups should be defined (see OECD, 2001), whether or not training should be voluntary, should it include driver assessment. The question of participation fees has been solved in varying manners in different countries.

Some examples of the educational resources and in some cases more detailed information can be found on the following web pages:

http://www2.ake.fi/ikaTOT/

- This is an Internet based self-test for older drivers, managed by the Finnish vehicle administration centre. The test can be done in Finnish or Swedish, and it comprises of 10 in-traffic photos with questions and an overall assessment of the traffic related knowledge.

http://www.dorset-cc.gov.uk

- Dorset county council's mature drivers' training course, carried out as discussions course with an option for on-road test performance. Aimed for drivers 55+.

http://www.cheshire.gov.uk/roadsafety/publications.htm

- This is a Cheshire county council's web-resource with lots of self-study material for different driver groups. The materials aimed for older drivers include information on, e.g., vision, medications, and driving.

http://www.aaafoundation.org/pdf/older&wiser.pdf

- This is a self-study leaflet for older drivers, published by the AAA foundation for traffic safety.

http://www.aarp.org/55alive/

- A web-resource maintained by the American Association for Retired Persons, for refreshing and retraining purposes, aimed for motorists 50+. This program has insurance discounts attached.

5 Safety measures on the level of the infrastructure

5.1 Road design

As discussed earlier in this report, older drivers do not dramatically differ from drivers in general in their driving performance. There are, however, some differences, which result (a) in differences in managing the driving task, and (b) in differences in experiencing the driving task. There are several ways to offer "external tools" for compensating for the difficulties older drivers can face (both in driving performance and subjective experiences). By means of road design, there are several measures that affect positively the premises for safe and comfortable driving for older drivers. These measures are usually advantageous for all drivers regardless of age.

Here, we shall focus on road design in those traffic situations and environments where older drivers experience most difficulties, that is, intersections and motorway exits/entries (interchanges). Of course, some of the guidelines for road design presented here (e.g., those regarding lightning and signing) also apply to other traffic environments and are of advantage as safety measures even outside intersections and interchanges.

This section is largely based on the 'Older Driver Highway Design Handbook' by Staplin, Lococo & Byington (1998) and its second edition 'Highway Design Handbook for Older Drivers and Pedestrians' (Staplin, Lococo, Byington & Harkey, 2001). These two handbooks contain recommendations regarding the design of highways including the references on which these recommendations were based. A major advantage of these handbooks is that all recommendations have been presented to engineers with the request to check whether these recommendations would contribute to a solution of existing problems of older drivers, and whether they would apply these recommendations to their own roads. Feedback from the engineers has been incorporated in the handbooks. As a result, both handbooks can be regarded as important reference books on the subject of road design elements that take the older driver into account.

However, since the infrastructure in the United States is rather different from that in Europe, and some of the recommendations might be at odds with the Sustainable Safety policy in the Netherlands and similar design policies in Sweden, it would not be wise just to copy all proposed measures. Therefore, before writing this section all recommendations have first been thoroughly screened with the help of Dutch engineers on the possibility and desirability to translate them to the European situation. Only those recommendations that were judged to be suitable for the European situation and that were related to intersections and interchanges were included, where possible complemented with the results of studies that were not included in the reference list of the American handbooks.

The included recommendations are ordered according to intersection types (intersections at-grade and grade separated interchanges) and within these intersection types to the road design elements to which they pertain. Each of the recommendations is preceded by a description of the importance of implementation of that particular recommendation.

5.1.1 Intersection design

Several studies have revealed that accidents at intersections are overrepresented among accidents involving at-fault drivers of 75 years and older (Hakamies-Blomqvist, 1993; 1994a; Zhang et al., 1998; McGwin & Brown, 1999; Davidse, 2000). Intersections can be defined as traffic situations that require complex judgements of speed and distance under pressure of time. Older drivers generally have more trouble in meeting these requirements than younger drivers have. According to Staplin, Gish, Decina, Lococo & McKnight (1998), intersection driving that is related to increasing safety risks and that becomes more apparent with age includes problems in using correct driving lanes, making turns, controlling the vehicle, and reacting upon the traffic situations.

With respect to infrastructural measures that might be able to improve the safety of older drivers, it is interesting to also know what the older drivers themselves indicate to be a problem. Benekohal et al. (1992) posed this question to a group of older drivers. Topics mentioned most often were: reading street signs in town, driving across an intersection, finding the beginning of a left-turn lane at an intersection, making a left turn at an intersection, following pavement markings, and responding to traffic signals. The same group of researchers also gathered information about the highway features that become important to drivers as they age. These included: lighting at intersections, pavement markings at intersections, number of left-turn lanes at an intersection, width of travel lanes, concrete lane guides (raised channelisation) for turns at intersections, and size of traffic signals at intersections. Mesken (2002) posed similar questions to older drivers in the Netherlands. Traffic situations in the proximity of intersections that were most often mentioned as being difficult were: making a left turn at an intersection without traffic lights, driving across an intersection without traffic lights, driving round a roundabout that has more than one lane.

Specific measures that apply to these and other road design elements are described in the following paragraphs.

5.1.1.1 View on the intersection

At the approach of an intersection, the view on other traffic approaching the intersection is largely determined by the angle at which crossing streets meet. The *optimal angle* is one of 90 degrees. A smaller angle makes it more difficult to overlook the intersection and to notice other road users. Road users can compensate for these difficulties by turning their head a little bit more. Since older road users generally have restricted head and neck mobility, they will however have more trouble with intersections where streets meet at a small angle. Therefore, a right angle junction is in particular important for older road users. A secondary benefit of a right angle junction is that it keeps the intersection area as small as possible, thereby reducing the chance of an accident.

Apart from the fact that older road users have more trouble overlooking the intersection because of a restricted mobility of head and neck, they also need more time to react (reduced perception-reaction time). A restricted view on the intersection, not only because of a small angle between the intersecting roads, but also as a result of shrubs, trees and buildings blocking the view on the intersection, leaves the driver little time to overlook the intersection and therefore also little time to react. The resulting pressure of time causes more problems for older drivers than for younger drivers. Therefore, a restricted sight distance or stopping sight distance has more adverse consequences for older drivers than for younger drivers. One can resolve this problem by using a longer perception-reaction time when calculating the *sight triangle* and the stopping sight distance, with a minimum of 2.5 seconds.

5.1.1.2 Assistance for turning left

Accidents while making a left turn represent the most important type of accident in the total number of accidents involving older drivers. These accidents are often the result of failing to yield. According to Knoblauch et al. (1995), drivers aged 75 and over are overrepresented especially in accidents occurring in left turns in stop- and yield-controlled intersections. Failing to yield may be caused by an erroneous judgement of the speed of the approaching vehicle, an erroneous judgement of the gap needed to join the traffic flow, or simply not noticing the approaching vehicle (Davidse, 2002; Dingus, Jahns, Horowitz & Knipling, 1998). These causes can be associated with several of the functional limitations that accompany old age, such as having trouble with motion and depth perception, and a decline in divided and selective attention.

On signalised intersections, failure to yield and any accidents resulting from it can be prevented by protected-only operations of the traffic signals (see Knoblauch et al., 1995). In that case there is no need for the driver to decide whether there is a possibility to turn left before approaching traffic arrives. In addition, a leading protected left-turn is recommended. This order results in fewer accidents and fits in with the expectations of the driver. To reduce confusion during an intersection approach, it is also recommended to use a separate signal for each lane of traffic. This also satisfies the older drivers' need for information on the lane assignment (see "lane-use control signs").

On stop- and yield-controlled intersections (and at intersections where protected-only operations are not possible, e.g. because of an unacceptable reduction in capacity) having opposite left-turn lanes, safety can be improved by adjusting the left-turn lane geometry. In general, more space on the lanes when turning would be beneficial especially to older drivers (Gutman & Milstein, 1988; Helmers, Henriksson & Hakamies-Blomqvist, 2004). Any signs, signals or aides to help the driver to better orientate to and acknowledge the upcoming turn also are beneficial (see Helmers et al., in press).

A good view on the stop- and yield-controlled intersections and easy understanding of their function are important. Opposite left-turn lanes and the traffic that uses these lanes can restrict the left-turning driver's view of oncoming traffic in the through lanes. The level of blockage depends on how the opposite left-turn lanes are aligned with respect to each other, as well as the type/size of vehicle in the opposing queue. Restricted sight distance can be minimized or eliminated by shifting opposite left-turn lanes to the right (positive offset) so that left-turning drivers do not block each other's view of oncoming traffic (Staplin, Harkey, Lococo & Tarawneh, 1997). Figure 3 shows the difference between opposite left-turn lanes that are exactly aligned (no offset) and the situation where the opposite left-turn lane is shifted to the right (positive offset).

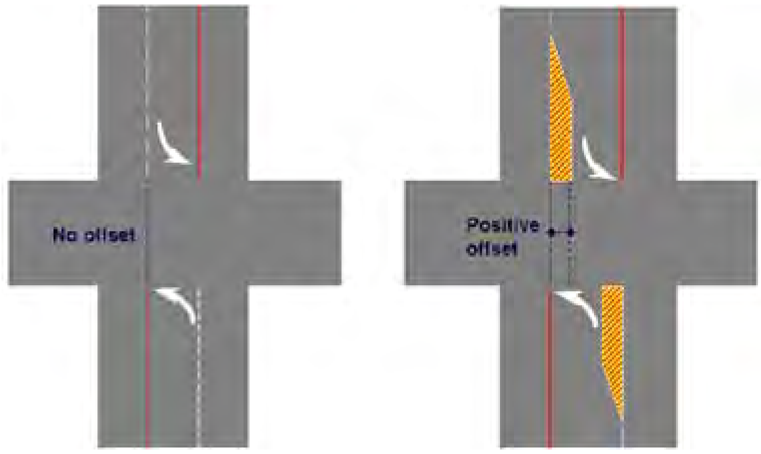
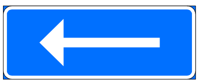


Figure 3 *No offset versus positive offset (Staplin, Lococo & Byington, 1998).*

It is not so much the degree of positive offset that matters, as does the sight distance that results from a certain positive offset. Left-turn lanes frequently used by heavy lorries need a larger offset, since these lorries have a more adverse effect on sight distance. McCoy, Navarro & Witt (1992) have developed an approach that could be used to compute the amount of offset that is required to minimize or eliminate the sight restriction caused by opposing left-turn vehicles. Where the provision of unrestricted sight distance is not feasible, stopping sight distance should be computed using a perception-reaction time of 2.5 second.

A possible negative side effect of a positive offset of channelised left-turn lanes (e.g. a parallel or tapered left-turn lane between two medians) is the potential for wrong-way manoeuvres by drivers turning left from an intersecting minor road. To prevent this, it is recommended to take the usual precautions against wrong-way driving (see section “Design to prevent wrong-way manoeuvres”), such as using (a) signs that indicate one-way traffic (*signs 1.4.11* and *1.2.2.*), (b) equipping channelised left-turn lanes with lane-use arrows and a white stop bar at the end of the lane, (c) using a retroreflective pavement marking to describe the path through the turn, and (d) using reflectorised paint and other treatments to delineate median noses in order to increase their visibility and improve driver understanding of the intersection design and function (Staplin, Lococo & Byington, 1998).



Sign 1.4.11

Sign 1.2.2

5.1.1.3 Roundabouts

Several advantages of the recommended road design elements regarding intersections are combined in modern roundabouts: left turns are completely eliminated, the driver has fewer decisions to make because of one-way traffic and yield-at-enter, lower speeds allow for more time to decide and act, and view on the intersection is not restricted by small angles between intersecting streets (Staplin et al., 2001; Davidse, 2000). Therefore, roundabouts could be relevant for the problems the older driver encounters when driving through intersections. All the more so, because roundabouts not only reduce the number of accidents, but as a result of lower speeds, also reduce the severity of crashes, which would be especially beneficial to older persons.

However, there are a few drawbacks. First of all, roundabouts are relatively new to motorists and older drivers are at a disadvantage in responding to novel, unexpected stimuli (Staplin et al., 2001; Davidse, 2000). This might even lead older drivers to avoid roundabouts. Simms (1992) reports avoidance of roundabouts by drivers over 70 (even in the United Kingdom), although it is unclear whether the roundabouts that were reported as being avoided were only multi-lane or also single-lane. Mesken (2002) did make a distinction between single-lane and multi-lane roundabouts when asking older drivers to indicate what they regarded as difficult traffic situations: whereas 22% of the drivers mentioned multi-lane roundabouts, only 3% mentioned single-lane roundabouts. It thus seems that older drivers at least prefer single-lane roundabouts. However, since the application of a multi-lane roundabout is a matter of capacity need, and the alternative of a multi-lane roundabout is a – generally less safe – signalized intersection, the application of multi-lane roundabouts may be unavoidable. Unfortunately, there are no observational studies available on the use of roundabouts by older drivers. Therefore, the following recommendations for roundabout design are based on a balance between human factors considerations regarding older drivers and general information on preferred practices regarding roundabouts.

Brouwer, Herland & Van der Horst (2000) state in their literature review on roundabouts in Sweden and the Netherlands that right angle connections are more effective in reducing driving speed and provide a better view of the traffic on the roundabout for the drivers that are about to turn onto the roundabout, than do tangential connections. Therefore, especially with the restricted head and neck mobility of the older driver in mind, it is recommended to use right angle connections to the roundabout. This recommendation is in agreement with the right angles recommended in the previous paragraph regarding the “view on the intersection”.

Another design element of roundabouts that is related to the view on traffic is the distance between the roundabout and cyclist and/or pedestrian crossings. For a driver leaving the roundabout to be able to have a good view on crossing cyclists and pedestrians that have right-of-way, he/she should be on a right angle with the cyclist/pedestrian crossing. This angle can only be obtained when the crossing is placed at approximately one length of a car from the circulation area (Linderholm, 1996, cited in Brouwer, Herland & Van der Horst, 2000; CROW, 1998; 2002).

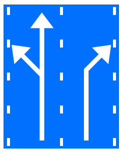
5.1.1.4 Traffic signing and marking in intersections

For a driver, it is important to successfully orient oneself into the upcoming traffic situation and navigate through it. The view onto other vehicles, but also the information gained from traffic signs, signals and road markings prior to the intersection and while driving through it are essential (see Helmers et al., in press). As people age, visual functions decline and people have more difficulty in dividing attention between, for instance, different aspects of the road scene, making it more difficult to detect traffic signs and obstacles, and hence to understand the traffic situation at hand. Staplin, Gish et al. (1998) list certain errors of this type that become more common with age. These include e.g., failure to react upon stop signs, driving against red light, failure to recognise signs, braking after every noticed sign or signal, and continue driving after stopping without making sure the route is clear. Road design elements can anticipate these difficulties by providing appropriate placement and legibility of traffic signs (e.g. street-name signs), conspicuity of obstacles (e.g. kerbs, medians and traffic islands) and recognizable intersection control (who has right-of-way) and lane assignment.

The importance of the legibility of street name signs has to do with the time and effort needed to read the name of the street (see Yanik, 1987). The more complex the traffic environment, the more time is required to react upon a sign (Helmers et al., in press). One can imagine the kind of danger that could result from a driver who is distracted from the basic driving task for a longer period of time or from a driver that suddenly brakes on approaching a street name sign (Taoka, 1991; Malfetti & Winter, 1987). Factors that influence the legibility of street-name signs are among others, contrast, luminance, font, letter height, letter width and interletter and interword spacing. These factors become more important as the eyesight of a road user becomes worse. Older drivers, because of their age-related deterioration of visual functions, need more contrast, a higher level of background luminance and larger letter sizes than younger drivers to achieve the same level of comprehension (see Helmers et al., in press). This can be accomplished by raising the requirements for letter size and retroreflectivity of street-name signs. The 'Older Driver Highway Design Handbook', (Staplin, Lococo & Byington, 1998), recommends a minimum *letter-height* of 150 mm for use on post-mounted street name signs on all roads where the speed limit exceeds 40 km/h. This letter height may seem high in comparison to European standards. Differences between the North-American and European infrastructure (e.g., road width) might explain a part of these differences but the fact remains that the older person will benefit from a higher letter height than is required for the average, younger driver (MUTCD states that the lettering on street name signs should be at least 100 mm high).

Since older drivers need more time to act (turning into a street) after having received directional information (e.g. a street name), the *placement* of street-name signs also is very important: older drivers should have sufficient time to prepare and execute their actions. Both visibility and prior notification can provide the driver with some extra time to act. Therefore it is recommended to place street-name signs post-mounted along the side of the road and to use advance street name signs to improve the visibility of street name signs on major roads and grade-separated junctions. Besides that, it is recommended to use retroreflective sheeting to provide increased sign conspicuity and legibility. When different street-names are used for different directions of travel on a crossroad, the names on intersection street name signs should be separated and accompanied by directional arrows.

The lane-use control signs also are of importance in intersections. Older drivers need timely warnings of changes in lane configuration. Arrow pavement markings that can provide this kind of information have the disadvantage of being liable to wear, being less visible in bad weather conditions and they can be covered by cars at the intersection. Therefore, it is recommended to use overhead lane-use control signs (*sign 1.5.1.4.*) in advance of the intersection as a supplement to pavement markings. Drivers should be able to read these signs at least 5 seconds in advance of the intersection (at operating speed; 50 meters at 36 km/h), regardless of the specific lighting, channelisation or delineation treatments implemented at the intersection (Staplin, Lococo & Byington, 1998).



Sign 1.5.1.4.

Other elements of the intersection that the older driver should be informed about as early as possible, are obligatory direction of travel and right-of-way. Research in the United Sates has shown that older drivers are overrepresented in wrong-way movements (Crowley & Seguin, 1986). To compensate for any visual or attentional problems, the most relevant information should be signalled in a dramatic manner to ensure that it receives a high priority for processing in situations where there is a great deal of complexity. This can be accomplished by more conspicuous signs, realized through provision of multiple or advance signs, as well as by placing signs in the driver's field of vision and using signs that are larger in size and have a higher level of retroreflectivity. To prevent wrong-way driving, these recommendations are particularly relevant for signs indicating one-way roads and 'no entry' (*signs 1.4.11* and *1.2.2*; see section "Assistance for turning left"). However, the same recommendations apply to traffic signs indicating stop-and yield-controlled intersections (*signs 1.2.50* and *1.1.23*), since accidents resulting from failure to yield also are overrepresented among accidents involving at-fault drivers of the age of 75 and older (Aizenberg & McKenzie, 1997; Zhang et al., 1998; Davidse, 2000). Moreover, Council & Zegeer (1992, cited in Staplin, Lococo & Byington, 1998) found that "young-old" drivers (65–74 years old) and "old-old" drivers (75 years and older) more frequently failed to yield and more often disregarded a stop-sign than a comparison group did (30–50 years old).

Sign 1.2.50

Sign 1.1.23

In addition to traffic sign related issues, consideration should also be given to the use of transverse pavement striping or rumble strips upstream of stop-controlled intersections where engineering judgment indicates a special need due to sight restrictions, high approach speeds, or other geometrical or operational characteristics likely to violate driver expectancy.

Road markings help the driver to maintain the correct lane position and give him/her a preview of the course of the road ahead. Because of their decreased contrast sensitivity (and their extended perception-reaction time) older drivers need a higher contrast between pavement markings and carriageway to be able to see the markings and have still enough time to act upon them, especially in darkness or in presence of glare. The same applies to the delineation of discontinuities, such as curbs of traffic islands and medians. The results of several focus group discussions have indicated that older drivers have difficulties in seeing these discontinuities, resulting in a possibility of running over them (Staplin, Lococo & Sim, 1990; Benekohal et al., 1992; Staplin et al., 1997).

Studies in the US have indicated that driver performance – measured by the probability of exceeding lane limits – was optimised when the perceived brightness contrast between pavement markings and the carriageway was 2.0 (Blackwell & Taylor, 1969; Allen, O'Hanlon & McRuer, 1977). This means that the pavement markings should be at least three times as bright as the carriageway. However, these studies were not specifically focused on the accommodation of older drivers. Another study compared the performance of the top 5 percent of 25-year-olds (the best performing younger drivers) with the bottom 5 percent of 75-year-olds (the worst performing older drivers). Taking the contrast requirements for the latter group into account, Staplin, Lococo & Byington (1998) recommend a minimum in-service contrast level of 3.0 between the painted edge of the carriageway and the road surface for intersections without overhead lighting. For intersections with overhead lighting a minimum in-service contrast level of 2.0 is sufficient.

In addition to the provision of a painted edge line on the road surface, it is recommended that all curbs at intersections (including median islands and other raised channelization) be delineated on their vertical face and at least a portion of the top surface. Vertical surfaces should be introduced by cross-hatched pavement markings.

5.1.1.5 Traffic signals and fixed lighting

As far as traffic signals and fixed lighting are concerned, it is important to take the visual limitations of older persons into account. In particular, the older drivers' need for increased levels of luminance and contrast should be weighed against their sensitivity to glare.

Since backplates provide more contrast between the traffic light and its direct surroundings without increasing the risk of blinding, they compromise between lighting, contrast and glare and are a good alternative to increased intensity of light. Background plates should only be omitted when the available space is such that the plate would be too close to the carriageway (CROW, 1996; s.n., 1997). Glare can be further reduced by reducing the intensity of traffics signals during darkness, except when this is unnecessary or undesirable because of the (fixed) lighting of the surroundings (s.n., 1997).

Apart from the recommendations regarding traffic light control that were mentioned in chapter "Assistance for turning left", it is recommended that an all-red clearance interval be consistently implemented, to accommodate age differences in perception-reaction time (Staplin, Lococo & Byington, 1998; CROW, 1996).

Proper lighting is more important to older drivers than to the average road user. Both the reduced pupil size and yellowing of the lens of the older adult reduce the amount of light reaching the retina. A consequence of this reduced retinal illumination is that sources must be of higher intensity to be seen at night (e.g. Olson, 1993). Furthermore, timely warnings of unexpected situations and changes in lane configuration and lane width are helpful to older persons because of their increased perception-reaction time and can be provided for by lighting these areas. Therefore, wherever feasible, fixed lighting installations are recommended (a) where the potential for wrong-way movements is indicated through crash experience or engineering judgement; (b) where twilight or night-time pedestrian volumes are high; and (c) where shifting lane alignment, turn-only lane assignment, or a pavement-width transition forces a path-following adjustment at or near the intersection (Staplin, Lococo & Byington, 1998).

5.1.2 Exit and entry of a motorway

Not only intersections at-grade pose a problem to older drivers, but also grade-separated interchanges. A study by Staplin & Lyles (1991) showed that drivers over 75 are overrepresented as the driver at fault in merging and weaving accidents near interchange ramps. With respect to violation types, the older driver groups were cited most frequently for failing to yield and for improper use of lanes. Similarly, Harkey, Huang & Zegeer's (1996) study of the pre-crash manoeuvres and contributing factors in older driver freeway accidents indicated that older drivers' failure to yield was the most common contributing factor. Age differences in interchange accidents and violations may be understood in terms of driving task demands and age-related diminished driver capabilities (Staplin, Lococo & Byington, 1998). Merging and weaving on interchanges make high demands on the information processing capacities of the driver. The driver must process a large amount of information during a short period of time and at high speeds, while maintaining or modifying his/her position within the traffic stream. Under these circumstances, several functional limitations of the older driver may come into play, among which a slower processing of information, reduced visual acuity and peripheral vision, and reduced flexibility of head and neck. Bad design may disrupt the merging performance by arousing erroneous expectations. In case merging and weaving take place in the dark or under bad lighting conditions, poor night vision and increased sensitivity to glare also may play a role.

During focus group discussions that were held as part of a study by Lerner & Ratté (1991), older drivers indicated that in their opinion interchanges could be improved by eliminating weaving sections and short merge areas and improving exit signing by better graphics and more information on upcoming exits.

Evidence of older drivers having problems with short merging areas also was found in the Netherlands (Mesken, 2002). Specific measures that apply to these and other road design elements are described in the following paragraphs.

5.1.2.1 Exit signing

The usefulness of directional information is dependent on its legibility and the time available to act upon the information. Older drivers, because of their age-related deteriorations of visual functions, need more contrast, a higher level of background luminance and larger letter sizes than younger drivers to achieve the same level of comprehension. This can be accomplished by raising the requirements for letter size and retroreflectivity of direction signs. Research has shown that the American standard for the height of capital letters (the "legibility index" of 50 ft/inch (6.2 metre per 10 mm letter height); also used in e.g. the Netherlands) exceeds the visual ability of 30 to 40 percent of drivers who are 65–74 years old, even under favourable contrast conditions (Transportation Research Board, 1988). Based on research by Olson and Bernstein (1979) and Olson, Sivak & Egan (1983) the 'Older Driver Highway Design Handbook' recommends to raise the legibility standard to one that assumes that a 10-mm tall letter is legible at 4 metres.

The time available to act on directional information can be improved by using multiple advance signing on exits and on lane configuration, which can be particularly useful for older drivers with increased time demands.

5.1.2.2 Design elements for acceleration and deceleration lanes

The problems older drivers encounter when merging were described earlier. Merging makes a high demand on several visual, information processing and physical abilities; abilities that decline as people age. In addition, the act of merging has to be performed under pressure of time, since the end of the acceleration lane restricts the opportunity to merge. Older drivers' difficulties in merging reveal themselves in the extra time needed to merge, at worst possibly ending in an accident. Therefore, the most important measure to be taken to improve the safety of older drivers' merging concerns the length of the acceleration lane. In a survey of drivers aged 65 and older, 49% of those surveyed reported that the length of motorway entry lanes was a highway feature that was more important to them now compared with 10 years ago (Benekohal et al., 1992, cited in Staplin, Lococo & Byington, 1998). Longer acceleration lanes provide the older driver with extra time to merge and at hence reduce the pressure of time. There is, however, no research available on the minimal length of acceleration lanes necessary to accommodate older drivers, and general guidelines on acceleration lane lengths differ between countries. For example, the Dutch guidelines prescribe longer lane lengths (350 m) than those recommended in the 'Older Driver Highway Design Handbook' (based on US guidelines; AASHTO, 1984). The fact remains though that the longer the acceleration lane, the better. In addition, a parallel design (instead of a taper design) should be used for entrance ramps to provide the driver with the ability to obtain full view of following traffic (Staplin et al, 1998).

As far as deceleration lanes are concerned, it is important to provide a good view on the following curve. The resulting information gives the driver the opportunity to assess the required vehicle control actions (braking, steering). The visibility of the curve can be improved by post-mounted delineators and chevrons (Staplin et al., 1998).

5.1.2.3 Fixed lighting at interchanges

The importance of lighting was mentioned earlier. With respect to motorways, fixed lighting should be implemented at exits and entries. The 'Older Driver Highway Design Handbook' recommends complete interchange lighting, but where this is not feasible, a partial interchange lighting system comprised of two high-mast installations per ramp is recommended, with one fixture located on the inner ramp curve near the gore, and one fixture located on the outer curve of the ramp, midway through the controlling curvature. In the case of a partial interchange lighting system, Dutch design guidelines recommend to additionally illuminate a part of the carriageway.

For evidence for the need of highway lighting by older drivers, Staplin et al. (2001) refer to the results of a survey by Knoblauch, Nitzburg & Seifert (1997, cited in Staplin, Lococo & Byington, 1998): 70% of the older drivers in the ages of 50 to 97 indicated that more lighting is needed on motorways, especially on interchanges, construction zones and toll plazas.

5.1.2.4 Design elements to prevent wrong-way manoeuvres

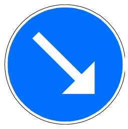
Accidents as a result of wrong-way driving account for only a very small part (± 1%) of the total number of accidents on motorways. This applies to all age groups, but with considerable differences between the age groups. Dutch figures show that the percentage of wrong-way drivers among drivers involved in an accident increases above the age of 55, with drivers of 70 years and older having the highest percentage (0.65% compared to an average of 0.06%). Looking at the wrong-way manoeuvres that led to a fatality or a serious injury, one third of the wrong-way drivers was aged 70 years or older (Blokpoel & De Niet, 2000). Staplin et al. (2001) report similar findings in studies by Tamburri & Theobald (1965, cited in Staplin et al., 2001) and Lew (1971, cited in Staplin et al., 2001): both studies showed that drivers above the age of 70 experienced the most wrong-way incidents and accidents.

An analysis of the official police reports of accidents in the Netherlands that were caused by wrong-way drivers showed that about half of the wrong-way manoeuvres that led to an accident, started on the exit road (De Niet & Blokpoel, 2000). These wrong-way manoeuvres occurred predominantly during darkness and involved older drivers (age 55 and older). Drivers wanted to enter the entry road to the motorway correctly but turned left too soon onto the exit road. De Niet & Blokpoel (2000) also did some supplementary research to find out to what degree road design could have played a role in wrong-way driving. To accomplish this, locations where drivers started wrong-way manoeuvres were visited. It turned out that these locations could have encouraged turning off prematurely by (1) a conspicuous exit and poor visibility on the entry, leading the driver to the exit road; (2) worn-out markings and misplaced or missing signs making it difficult to know what is permitted; and/or (3) a curve of the subordinate road onto the exit that is not tight enough to hinder a premature turn-off.

Measures intended to prevent the most important cause of wrong-way driving among older drivers (tuning off prematurely) mainly focus on making the entry more conspicuous: the attention of the driver should be drawn to the entry. Compliance with the existing specifications for the signing and visibility of entries and maintenance of markings are amongst the most important measures to be taken to prevent wrong-way driving. Furthermore, it has been shown that the "Do not enter/go back" signs used in the Netherlands to warn drivers not to enter the exit (see *Dutch sign C2/503*), and located in the median between the exit and entry on half cloverleaf junctions, often can be seen and, therefore, also seem to be intended for drivers on the entry. Due to this false alarm, drivers learn to ignore the signs; which can reduce the effectiveness of signs, or even have an adverse effect. For this reason, it is recommended to place the signs (or shield them) in such a way that they cannot be seen and do not appear to be intended for traffic on the entry. Also recommended is the application of wrong-way arrow pavement markings near the terminus on all exit ramps, accompanied by red raised-pavement markers facing wrong-way traffic. Where adjacent entrance and exit ramps intersect with a crossroad, the use of a median separator is recommended, with the nose of the separator delineated with reflectorised paint and extending as close to the crossroad as practical without obstructing the turning path of vehicles.

In addition, it is recommended that the ‘obligatory direction of travel’ sign (*sign 1.3.2.1.*) be posted on the median separator nose (De Niet & Blokpoel, 2000; Staplin, Lococo & Byington, 1998).

Dutch sign (C2/503)



Sign 1.3.2.1.

5.2 Vehicle design

5.2.1 Design to improve driving conditions

As already noted, many of the age-related physical changes and deficits do not affect the observed quality of driving performance but can affect the subjective experience of driving. The same conditions, i.e., arthritis, pain in joints, muscular stiffness, and decreased muscular strength that make it difficult to walk, bike and access the public transportation system can make driving very uncomfortable though not affecting the driving performance as such. There is only little to do about the difficulties these conditions cause to walking and biking. However, the comfort of driving can be helped with proper design.

Better design to ease the older persons’ entry and exit of the car has been suggested by studies (Institute of Consumer Ergonomics, 1985; Petzäll, 1991; for a review see OECD, 2001). These suggestions include better design in placing handholds, door height, and seat adjusting. Also swivel seats, additional handles and additional steps have been suggested to ease the exit and entry of an older driver (OECD, 2001).

Overall, more adjustable in-vehicle equipment has been seen as useful for older drivers. This includes powered steering and adjustable controls, seating, and mirrors (OECD, 2001). This kind of design that improves the in-car driving conditions is likely to enhance safety in two ways at least: by enabling the older persons to keep up driving even after certain age-related deficits (which actually in general enhances both mobility and safety), and by enabling the driver to concentrate more on the driving task itself when the physical conditions have been made more comfortable.

5.2.2 Design to protect the occupant

Another type of design that can be seen as a safety measure is design to protect the driver and passengers, i.e., to increase passive safety. This includes restraint systems like seatbelts and airbags, improved vehicle crashworthiness, and better structural performance of the vehicle. This type of design has historically been the most usual vehicle safety improvement, and it has been directed to drivers of all ages (OECD, 2001). It has been very effective in improving the safety of car occupants (e.g., Newstead, Cameron & Le, 2000). Though designed for all, these design improvements benefit older drivers especially because of their frail body and increased vulnerability.

However, the frailty of the older persons’ body can also be a disadvantage with the protective design. In some crash circumstances, seatbelts may cause further chest injuries for older vehicle occupants (OECD, 2001). Overall, seatbelts are beneficial to older car occupants, but the special needs and antropometric characteristics of the older population should be taken into the further design processes.

Another considerable point regarding older car occupants is the vehicle mass. A larger car is beneficial to an older driver or occupant, since it reduces the risk for serious injury in a crash situation (OECD, 2001).

Overall, design improvements to better protect older drivers and passengers are an important safety measure, since the frailty of older persons is a major contributing factor on the fatalities and serious injuries of older road users. In a way it can be seen as an "external compensation" for older drivers. In the following paragraph, the more internal and cognitive performance directed compensatory aids, based on ITS, will be discussed.

5.2.3 Intelligent Transportation Systems relevant for older drivers

Often, infrastructural measures that take the older driver into account also help younger drivers. At a certain point however, it is possible that infrastructural measures designed to aid older drivers may for instance lead younger drivers to drive at higher speeds because they have such a great view of what is coming. Therefore, there are limits to the possibilities of making the driving task easier by taking infrastructural measures. This is where Intelligent Transport Systems (ITS) come in. In general, ITS encompass a broad range of communications-based information, control and electronics technologies. When integrated into the transportation infrastructure and into vehicles, these technologies help to monitor and manage traffic flow, reduce congestion, provide alternative routes to travellers, and help the travellers to navigate in a traffic system in ways that enhance safety and comfort while driving. In this section we shall look at ITS as in-vehicle assistive devices that can – in a more personal way – further improve the safety of the older driver. With this objective in mind, ITS will be described from the perspective of the objective need of the older driver, as opposed to a description of the range of ITS-applications that has been introduced by the industry. Furthermore, the objective need will be based on road safety considerations and not on mobility considerations (see e.g., Färber (2000) for a review of ITS that might improve older persons' mobility).

5.2.3.1 ITS-applications that can compensate for the effects of ageing

Several studies have identified Intelligent Transport Systems that might be able to provide tailored assistance for older drivers (see e.g. Shaheen & Niemeier, 2001; Färber, 2000; Mitchell & Suen, 1997). ITS that according to Mitchell & Suen (1997) might be able to provide assistance for difficulties resulting from limitations in (a) motion perception, (b) peripheral vision, and (c) selective attention are:

1) collision warning systems aimed at intersections (a);
2) automated lane changing and merging systems (a,b);
3) blind spot and obstacle detection (a,b);
4) in-vehicle signs (c);
5) intelligent cruise control (c).

Entenmann & Küting (2000) describe a system that might be able to provide support for difficulties resulting from (d) decreased speed of processing information and decision making: a system that (6) assists the driver in crossing complex intersections.

In this section on ITS, focus will be on the six above-mentioned ITS; a selection of ITS completely based on road safety considerations. As a result, some of the ITS that are often mentioned in the literature on older drivers and ITS will not be discussed, such as night vision enhancement systems (VES; UV headlights or infrared technology to provide night vision), navigation systems and emergency callout (mayday) systems that automatically report the location of a vehicle in the event of a breakdown, accident or other emergency. These systems seem to help drivers having difficulties driving at night, driving in unfamiliar areas and having subjective feelings of insecurity, respectively (Oxley & Mitchell, 1995; Mitchell & Suen, 1997). In general, these systems could be helpful for older drivers from a mobility perspective, whereas mayday systems also might reduce accident severity. Older drivers will feel more secure with these systems installed, and will keep on driving in situations they would otherwise avoid, such as driving at night and driving in unfamiliar areas (Oxley & Mitchell, 1995).

Especially for VES one could ask the question what the safety consequences of these systems would be. Older drivers generally compensate for their impaired night time visual acuity and sensitivity to glare by avoiding to drive at night. As a result, the number of accidents involving older drivers at night is relatively low (Hakamies-Blomqvist, 1994a; 1994c; Aizenberg & McKenzie, 1997; Zhang et al., 1998; McGwin & Brown, 1999). When the large-scale introduction of night vision enhancement systems encourages older persons to drive again at night, this will increase their mobility and improve their quality of life. However, it has to be seen whether the use of night vision enhancement systems will provide a similar risk compensation for impaired nighttime visual acuity as does the older driver’s compensation strategy of not driving at night (see Caird, Chugh, Wilcox & Dewar,. 1998 for a review of VES).

5.2.3.2 An evaluation of ITS that might improve road safety for older drivers

This paragraph describes the functionality of the six selected ITS. As will be noted, many of the described systems are still under development, mainly because the type of technology that is needed to provide the specific kind of assistance is not yet available. For those systems that have already been tested among older drivers, effects on road user behaviour will be described.

Collision warning systems aimed at intersections

Collision avoidance systems that would be most useful for older drivers will draw the attention of the driver to traffic that approaches the same junction. Such a collision warning system fits the most important driving difficulty of older drivers: turning left on an intersection. However, junctions also represent the most complex situation to analyse for collision detection, since vehicles can approach from ahead or either side, and can continue straight through the junction or turn (Mitchell & Suen, 1997). Consequently, Mitchell & Suen (in 1997) expected equipment to protect against junction collisions to take the longest time to develop. By now, in 2004, the Japanese Ministry of Land, Infrastructure and Transport is testing a system that seems to offer the desired functionalities. The system that is being tested is the so-called ‘Smart Cruise System’ (also known as the Advanced Cruise-Assist Highway System AHS), a system that offers seven support services, among which a support system for prevention of crossing collisions and a support system for prevention of right turn collisions (in Japan people drive on the left side of the road). All services will be tested separately on a proving ground, amongst others paying attention to safety effects and the convenience for users (Ministry of Land, Infrastructure and Transport, 2002). Unfortunately, test results for the two above-mentioned services that would be particularly useful for older drivers have not been published yet.

Another collision warning system that is aimed at the prevention of accidents on intersections, was developed for the DRIVE-II-project EDDIT (Elderly and Disabled Drivers Information Telematics). This system was simulated and tested in a driving simulator. It provided the driver with a colour light indication of whether the next gap in the stream of traffic was long enough to allow a safe turning manoeuvre to be made; if the gap was at or longer than a selected threshold of 6 seconds, a green light indicated that is was safe to make a turn, otherwise the light changed to red. It remained red until the on-coming vehicle passed the test car, whereupon the device measured the gap to the next vehicle in the on-coming traffic stream. The collision warning system was only active when the test car was stationary waiting to turn (Oxley & Mitchell, 1995).

The safety effects of the simulated system were deduced from the time to collision. The test results showed that the time to collision was smaller when subjects were using the system than when they were not; so the system resulted in more near misses. Apparently the system sometimes advises older drivers to accept a gap that is shorter than they would like. The time needed to make the turn could play a part here; some drivers made their turning manoeuvre relatively slowly. Based on these results, Oxley (1996) recommends that a collision warning system should have the gap adjustable to match individual driver requirements (e.g. reaction times): uniform settings would be at best unhelpful, at worst dangerous.

All the older subjects said that the system was useful or very useful at night. By day, 63 per cent of the older drivers found it useful or very useful. About half of the older drivers would have been willing to pay for the system (Oxley & Mitchell, 1995).

Automated lane changing and merging

Equipment for automated lane changing and merging will assist the driver in selecting a gap and also take care of the actual changing or merging. These systems go further than just informing or warning the driver: they take over vehicle control for a short period of time. Such kind of support is currently not available. Mitchell & Suen (1997) expect these systems only to be available between 2010 and 2030.

A simplified form of assistance for lane changing and merging is being offered by collision warning systems. Regan, Oxley, Godley & Tingvall (2001) discuss lane-change collision warning (LCCW) systems and lane-change collision warning and avoidance (LCCWA) systems. As their names already suggest, the first system only alert the driver to objects in the vehicle's blind zones, whereas the second system also automatically steers away from the object. In this respect, the latter comes closer to automated lane changing and merging systems.

According to Regan et al. (2001), only LCCW systems are currently available on the market.

Evaluation studies of the use of LCCW systems by older persons are not available. In general, LCCW systems have several disadvantages, such as high false alarm rates and the close lateral proximity of vehicles that makes it hard for a driver to safely steer away from the object (Tijerina, 1999; Dingus et al., 1998).

Blind spot and obstacle detection

The LCCW systems that were described in the precious section alert the driver for vehicles located in the blind spots of their own vehicle. Another type of system that provides similar support, detects objects close to a slow-moving vehicle. Those systems can prevent the kind of accidents that can occur while parking. In comparison to the other accident types this type of accident has less relevance for road safety, both in terms of occurrence and accident severity. However, older persons may be inhibited from driving because of these accidents or from travelling to some destinations because of the difficulty with parking. In the EDDIT-project mentioned earlier, two types of reversing aids were tested. Both reversing aids enabled the drivers to park much closer to objects and therefore to park more easily in tight parking spaces. The older drivers' responses to both reversing aids were very positive. The majority found it useful and easy to use (Oxley & Mitchell, 1995).

In-vehicle signs and warnings

The projection of signs and warnings in the vehicle uses the technology of transmitting the content of a road sign from the roadside to a vehicle and to display a replica of the sign, either on a screen in the dashboard or via a head up display. That way, signs can be read more easily, and they will be available for a longer period of time. According to Mitchell & Suen (1997), widespread application of in-vehicle signs and warnings will require national or international standards for the transmission of roadside information, and considerable investment in road side transmitters.

Lee (1997) points at the tendency of In-vehicle Signing Information Systems (ISIS) to focus driver attention to in-vehicle displays and away from the roadway. According to Lee, the ease of processing ISIS information may compensate for this shift in attention, particularly since ISIS displays will not be subject to environmental factors (rain, snow and fog) that can obscure roadway signs. However, a greater proportion of the driver's attention will now be in-vehicle, potentially leaving insufficient attention for environmental scanning (Lee, 1997). Due to the functional limitations of the older driver, especially their increased difficulty to divide attention between the basic driving task and other activities, ISIS might have more adverse effects on the older driver's driving behaviour. The location of the in-vehicle display and the way the information is provided are important factors as to whether the safety effects of the in-vehicle signs and warnings will be positive or negative (Stamatiadis, 1998; Pauzié, 2002; Luoma & Rämä, 2002).

Intelligent cruise control

Systems that offer intelligent cruise control (ICC) (also known as Adaptive Cruise Control (ACC)) not only see to it that the vehicle maintains the same speed, but also incorporate a distance keeping function. Depending on the type of ICC the system will alert the driver or take over the control. Since older drivers have a higher than average number of accidents that involve failure to comply with rights of way such as yield or stop signs, or traffic signals, future ICC systems should also assist drivers to avoid these classes of error (Mitchell & Suen, 1997).

There have been few behavioural studies conducted to examine the effects of ACC on driving performance (Regan et al., 2001). In general, behavioural studies (both simulator studies and field trials) have shown that ACC led to more even speed and headway distributions, but at the same time they led to higher driving speeds, smaller minimum headways, and harder and later braking when a stationary vehicle emerged ahead (Nilsson, 1996; Hoedemaeker& Brookhuis, 1998; Fairclough & Humphries, 1995; cited in Regan et al., 2001). On balance these data suggest that ACC is more likely to enhance the comfort of drivers than to enhance their safety (Regan et al., 2001).

Since speeding and tail-gating are less common among older drivers, current ACCs might not be that relevant for the safety of older drivers. Nevertheless, it is interesting to note that a recent study on the effect of ACC (providing both speed and distance control) on driving performance of both younger (<25 years) and older drivers (>60 years) has shown that older drivers adapted to the ACC system in a similar manner as younger drivers (Brook-Carter, Parkes, Burns & Kersloot, 2002). Driving performance was measured in terms of speed, lateral position, headway and crashes. The older drivers did, however, not experience the benefit of a reduction in workload when driving with ACC. According to the authors, this implies that although older drivers were able to use the ACC, they had to work harder in order to achieve this.

Driver information system for demanding urban traffic situations

The driver information system described by Entenmann & Küting (2000) is a navigation system not only giving route descriptions, but also providing timely information on the crucial elements of the next traffic situation. By giving the driver very early and sequential information, the driver will be able to build up a mental picture of what to expect. This mental picture will give him/her the possibility to direct his/her attention to the most important traffic objects. Given their functional limitations as described earlier, a support system that provides this kind of information would be especially useful for older drivers. This group of road users is also the target group of Entenmann & Küting, who both work at DaimlerChrysler: Older drivers are not only the main customers of Mercedes-Benz of today, but their share in society is also constantly growing.

According to Entenmann & Küting (2000), the information that should be provided by a driver information system as the one described above, should be restricted to an indication of the complexity of the intersection, the number of lanes and the traffic objects that deserve attention (e.g., a pedestrian crossing). Since digital maps currently do not contain this kind of information, Entenmann et al. (2001) carried out a pilot to explore the possibilities of adding the above-mentioned information to digital maps. This pilot was carried out in the framework of the NextMAP project, a partnership of map providers and car manufacturers. It turned out that it was technically feasible to collect and digitise the information that was needed.

As part of the same pilot, Entenmann et al. (2001) also carried out a field test to investigate the user acceptance of this kind of driver information system and its effects on driving behaviour. The device that was actually used in this test supported the driver in adjusting the vehicle speed to the speed limit, in selecting the appropriate lane, and in negotiating intersections. Unfortunately, the published test results contain very little detail. All that is said about the test results is that "information about lanes, speed limits and priority regulations are very beneficial for the driver in demanding urban traffic situations and was very well accepted. The additional information eases the driving task significantly and increases driving safety compared to a standard navigation system."

5.2.3.3 User acceptance

As far as the willingness of older persons to buy and use ITS is concerned, it was already mentioned that the results of the EDDIT-project showed that older drivers who participated in this project found the systems useful and said that they would be willing to pay substantial prices to have the systems in their own cars (Oxley & Mitchell, 1995). The EDDIT-project did not only evaluate the use of the collision warning system that was described earlier, but also evaluated the use of other ITS such as route guidance systems, emergency alert and reversing aids. All these systems were considered useful by the older drivers. According to Oxley & Mitchell (1995) "there is no evidence of resistance to the introduction of these systems and the prices drivers indicated that they would be willing to pay were quite realistic for the emergency alert and reversing aid and were approaching a realistic price for route guidance. This finding is consistent with the results of a review of elderly people's car purchasing habits made at the start of the project, where it was found that they tended to buy smaller cars but with a higher specification than younger drivers; they were prepared to pay for 'extras' such as power-assisted steering and electrically-operated windows, provided that those extras met a real need".

In a more recent Swedish questionnaire study (Viborg, 1999), similar results were found. Asked about their attitudes towards 15 in-car information systems, older drivers (65 years and older) had a more positive attitude toward the presented ITS than younger drivers (30–45 years). Systems that older drivers more often rated as useful as compared to younger drivers were automatic speed adjustment systems (adjustment to the speed limit or to slippery and foggy conditions), automatic distance adjustment systems, crossing warning systems and left-turn-crossing warning systems. ITS that provide speed adjustment and distance adjustment (ICC), and ITS that warn the driver by a signal if it is unsafe to pass through or turn left on an intersection (collision warning systems aimed at intersections) were described earlier in this text. Since the former systems (partly) take over vehicle control, Viborg (1999) suggests that older persons seem to be more willing to accept enforcing systems.

De Waard, Van der Hulst & Brookhuis (1999) made the same conclusions based on the results of their simulator study testing the effects of an in-car tutoring system on driver behaviour. Drivers were provided with auditory and visual tutoring messages in case they were speeding, not coming to a stop before a stop sign, running a red light, or entered a one-way road from the wrong direction. Both older (60–75 years) and younger drivers (30–45 years) made fewer violations if the system gave feedback messages. But whereas the older drivers were pleased with the messages, the younger drivers disliked the system.

The above-mentioned research on user acceptance indicates that the ITS described earlier might well be accepted by older drivers as a means to increase their safety. But whether a specific device will actually lead to a reduction of the number of accidents will also depend on its design, for instance in terms of its attentional demands. This topic will be covered in the next section.

5.2.3.4 Design guidelines for ITS-applications

Older drivers are most likely to suffer the effects of poorly defined ITS applications (Stamatiadis, 1994, cited in Regan et al., 2001). Hence it is critically important to design the human machine interface for ITS applications with the limitations and capacities of older drivers in mind (Regan et al., 2001). Caird, Chugh, Wilcox & Dewar (1998) have given an overview on the current guidelines. As opposed to most guidelines, they have written the guidelines in the form of “dos” instead of “don'ts”, to be of help for designers of ITS. Furthermore, they have not only included the original guidelines, but also the references of the empirical evidence the guidelines were based upon (see Stevens et al. (2002) for a similar approach). Apart from a section on general guidelines pertaining driver information requirements; manual control; visual display; display location; in-vehicle display design (legibility, understandability); driver attention, workload and safety; training issues and requirements; and user interface requirements, they have also included a special section on older driver guidelines, based on guidelines proposed by Dingus et al. (1996), Kline & Scialfa (1997) and Granda et al. (1997). These design guidelines are summarized in Table 3 along with the functional limitations of older persons they take account of. Some of the descriptions have been taken from Gardner-Bonneau & Gosbee (1997).

Whereas the guidelines in Table 3 all have been selected on the basis of the older person’s probable limitations, it should be kept in mind that designers should also take advantage of the experience that older drivers have. This can be accomplished by using familiar features that are common to them, such as traffic-related icons, or features that are common to other products used by the elderly (Gardner-Bonneau & Gosbee, 1997).

Table 3 Functional limitations and relevant design principles (based on Caird et al. (1998) and Gardner-Bonneau & Gosbee, (1997).

Functional limitations	Relevant design principles
General sensory deficits	Use redundant cues, like auditory, visual and tactile feedback
Visual acuity	Increase character size of textual labels
Colour vision	Use white colour on a black background
Diminished low-light vision	Use supplemental illumination for devices used in low-light conditions
Sensitivity to glare	Use matte finishes for control panels and anti-glare coating on displays
Hearing	Use auditory signals in the range of 1500–2500 Hz range
Depth perception	Where depth perception is important, provide cues not dependent on stereoscopic vision, such as relative size, interposition, linear position, and texture gradient
Selective attention	Enhance the conspicuity of critical stimuli through changes of 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

5.2.3.5 Concluding remarks on ITS and older drivers

Based on the material described above, we can conclude that with respect to ITS that aim at an improvement of the safety of the older driver, much research still has to be done. First of all, initiatives like those of Entenmann & Küting (2000) will have to be followed to arrive at a situation in which more ITS are being developed that target the special safety needs of older drivers. Besides that, existing ITS should more often be evaluated using both younger and older drivers. As Green (2001) states, older drivers experience considerably more difficulty in completing telematics tasks, and therefore it is essential that safety and usability evaluations focus on them. If the older drivers are able to complete a task safely and easily, then so will other drivers.

5.2.4 Summary: General principles for infrastructure design

Some general principles can be formulated for infrastructure design. These apply to all road users but may be of special importance for seniors. The following presentation is based on Helmers et al. (in press).

1) Roads should be built according to standards reflecting their function so that the expectations of the road user about how the road will continue and how other road users will behave are verified.
2) The road environment should contain as much as possible redundant information; in other words, all elements in the road environment should give an identical message about the function of the road.

3) A correctly constructed road will both create correct expectations in the driver and support effective information processing by creating good preconditions for automatising subtasks.
4) The road should be constructed so that the driver is allowed enough time to perform a demanding task in controlled mode.
5) Intersections should be built so that the drivers can without difficulty understand the layout and function of the intersection and that they also have a clear continuous experience of where in the intersection they are while driving through it.
6) Roads should be built so that the mental load of the driver is neither too low nor too high; normally, the load should be decreased in intersection and increased between them.
7) Road signs should be placed in locations where the driver needs them and can take the time to read them.
8) To navigate is a strategic problem-solving task. Therefore, navigating information should be logical and hierarchical in nature and consequent.
9) Information supporting tactical decision should be readable at sufficient distances. Similarly, road markings and other elements supporting operational decisions should be visible early enough to be usable.

6 Conclusions and recommendations

The present report has focused on older drivers' problems and possible countermeasures from a safety point of view. However, measures aiming at better safety often can serve even other transport political goals, such as mobility or equity. For an example, design features making the car easier to use for older drivers facilitate the driving task, which is likely to increase safety but they also may have positive effects on mobility, making driving more pleasurable, and finally on equity by helping a subpopulation at risk of social exclusion to keep themselves mobile and active.

Rumar (1999) has made a distinction between different levels of safety problems that is especially useful in the context of ageing and transportation. According to Rumar, first level problems are those emerging directly from accident statistics and whose countermeasures tend to be relatively straightforward. For older road users generally, their physical frailty is such a first order problem and the obvious countermeasures are, for example, to increase physical protection in cars and to plan the traffic environment in such a manner that the likelihood of falls on pavements and of conflicts between pedestrians and bicyclists is minimised. For drivers, there are certain design characteristics that are likely to decrease mental load and to help older drivers to cope.

Second order problems are, according to Rumar, factors that reduce the effectiveness of countermeasures targeting first order problems. For older drivers, one example might be enforcement of speed limits. Older drivers themselves seldom speed, but careful observation studies have shown that the likelihood of merging accidents (in which the older driver will be at fault) increases if the potential counterpart is a younger driver who drivers at a higher speed than anticipated by the older driver trying to merge (Keskinen, Ota & Katila, 1998).

Third order road safety problems are hidden and do not deal directly with the traffic situation but rather with underlying factors such as organisation and management of road safety work and the knowledge base and values on which safety work is grounded. Again, with respect to older road users, an example of a third order problem is the common misconception that older drivers are a risk for the society.

At present, our greatest problems when trying to develop sound policies for the transportation of the ageing European societies seem largely to be on the third level. In order to make possible and facilitate second and first level safety efforts we need to target certain third order problems first. Below are some concluding recommendations of third level safety measures.

1) A sound research evidence based view of the complex problems of ageing and safe transportation should be implemented among decision makers. Viewing traffic safety in a public health perspective will be useful in balancing the legitimate demands of the ageing citizens concerning both mobility and safety.
2) A broad collaboration should be established between different areas of policy making, notably land use, health care, and transport planning. Again, in a public health perspective, constructing the "big picture" of older road users safety on the basis of both police and hospital statistics, including falls (=pedestrian single accidents), will help to get a more balanced view of the safety of different travel modes. It will also help to avoid apparent "black holes" in budgeting, e.g., when investments in the road environment produce

costs within the transportation sector but the gains “disappear” somewhere in the health care sector.

3) In line with the idea of Active Ageing brought forward by the WHO, safety work focusing on older road users should aim at encouraging people to actively participate in the planning, implementation and evaluation of their transportation options. An active participation of both the current and the future older road users will ensure the use of locally adequate and user-specific expertise, which in turn will lead to good acceptance of different safety actions.
4) Finally, it is necessary to extend the broad collaboration effort to other relevant actors who may not yet fully realise their potential role in this context, such as the insurance branch, the car industry, etc. In car design, for example, the problem is not so much to know what to do: there exist a number of technical solutions that we know might be good for the comfort and safety of older users. Rather, the problem is one of implementation: how to make the manufacturers include such features in their design specifications.

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