Alena Erke
TØI report 972/2008

Institute of Transport Economics
Norwegian Centre for Transport Research

Making Vision Zero real: Prevention of accidents and injuries among elderly pedestrians

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Author(s): *Alena Erke*

Forfatter(e): *Alena Erke*

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Summary:
In a literature review and analysis of accident statistics it has been found that older pedestrians in many ways are a disadvantaged group of road users. They have increased accident risk and are more vulnerable to injuries. They also suffer more serious and long-lasting impairments when injured, including reduced life expectancy and reduced quality of life. Safety and mobility are closely related. Physical activity is related to reduced risk of accidents and severity of injuries. High accident risk in road traffic is often associated with reduced walking. Safety measures are most promising when they increase physical activity, e.g. by physical and motivational training, by providing practical aids, and by making pedestrian infrastructure less complex, less demanding and more attractive. Addressing specific functional impairments seems less promising.

Sammendrag:
I en litteraturoversikt og en analyse av ulykkesstatistikk ble det funnet at eldre fotgjengere har høyere ulykkesrisiko og er mer utsatt for alvorlige skader. Skader har ofte mer langvarige konsekvenser og kan medføre større reduksjoner av livslengde og livskvalitet. Sikkerhet, trygghet og mobilitet henger tett sammen. Fysisk aktivitet kan redusere risikoen for ulykker og skader. Eldre fotgjengere som blir skadet i trafikken eller som føler seg utrygge går som regel mindre enn andre eldre fotgjengere. Tiltak for eldre fotgjengere er derfor mest lovende når de stimulerer fysisk aktivitet og øker tryggheten. Dette kan være fysisk trening, praktiske hjelpemidler og bedre tilrettelegging av infrastruktur for eldre fotgjengeres behov (for eksempel reduksjon av kompleksitet). Tiltak rettet mot spesifikke funksjonssvekkelser synes mindre lovende.

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Preface

This report is part of the operationalization of Vision Zero. The main focus is on accidents and injuries among elderly pedestrians. It summarizes risk factors, accident statistics, and safety measures for reducing the accident and injury risk of elderly pedestrians.

The project has been funded by the Norwegian Ministry of Transport and Communications. Our contact person at the Ministry of Transport and Communications has been Marte Lillehagen.

Project manager at the Institute of Transport Economics has been Alena Erke who has also written the report. Quality check was performed by Rune Elvik.

Oslo, June 2008
Transportøkonomisk institutt

Lasse Fridstrøm	*Marika Kolbenstvedt*
Managing Director	Head of Department

Contents

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Summary:

Making Vision Zero real: Prevention of accidents and injuries among elderly pedestrians

Elderly pedestrians are in many ways a disadvantaged group of road users. They have an increased accident risk and more severe injuries once involved in an accident. They also suffer from more long-lasting impairments when injured, including loss of life years and reduced quality of life. High accident risk, a subjective feeling of insecurity or sustained injuries all are likely to reduce walking and thereby physical activity. High physical activity is associated not only with higher mobility and quality of life, but also with reduced risk of accidents and injuries. Safety measures are most promising when they increase physical activity, e.g. by physical and motivational training, by providing practical aids, and by making pedestrian infrastructure less complex, less demanding and more attractive. Addressing specific functional impairments seems less promising. This has been found in a review of international literature and analyses of Norwegian accident statistics.

Elderly pedestrians have larger risk of accidents and injuries than younger pedestrians and injuries have more severe consequences for quality of life.

Elderly pedestrians are no precisely defined group of road users. “Elderly” refers to the fact that accident and injury risk increase as a function of increasing age. The age from which walking becomes more dangerous lies around 60-70 years. There are large individual differences, depending on the degree of physical and mental activity, illness, and other factors.

Changes of cognitive and physiological functions, behaviour and attitudes, and increasing vulnerability are contributing factors to the increase of accident and injury risk.

Contributing factors to increasing accident risk are complex, they may compensate or reinforce each other, and it does not seem possible to identify any single “responsible” factors.

A number of perceptive and cognitive functions are declining with increasing age, a fact which is often assumed to contribute to increased accident risk. These deficiencies are however to a large degree compensated, either by changed behaviour or by increased experience, changes in attitudes, lifestyle etc. No systematic relationships have for example been found between sight (visual accuracy), hearing or cognitive abilities (except dementia) and accident risk.

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Performance changes that have been found to be related to increased accident risk are reduced processing speed, selective and divided attention. These changes cause difficulties mostly in situations that are complex or require quick reactions. Reduced visual performance, especially the useful field of visual and peripheral vision, is also likely to be a contributing factor in accidents, including falling accidents. Reduced strength and motor abilities may contribute to accidents as well, e.g. by increasing crossing times, reducing the possibilities to jump out of the way and by increasing the risk of falling accidents. Numerous other changes that occur with increasing age may also contribute to accident risk, both positively (e.g. increasing experience, compensating strategies, increased caution) and negatively (e.g. anxiety, overcaution, decreased compliance with traffic laws).

Finally, vulnerability increases with increasing age, mainly due to increased risk for fractures and longer recovery periods. Injuries have therefore frequently more serious and more long-lasting consequences among older people.

Older pedestrians are most at risk in situations which are complex or require quick judgements and actions.

In general, all traffic situations which are complex or require quick responses increase the accident risk of pedestrians. Accident types where older pedestrians are overrepresented are therefore intersection accidents and accidents involving a pedestrian crossing a road, especially a road with four or more lanes or an unsignalized pedestrian crossing. These findings are based on international research. In Norwegian accident statistics less pronounced differences between accident types can be found.

Older pedestrians are more at danger of falling accidents, and falling accidents have more severe consequences among older than among younger pedestrians.

Falling accidents occur far more often among older pedestrians than among younger ones, and they have more severe consequences among older people (hip fractures). Falling accidents are likely to be much more frequent than collisions with motor vehicles. Data are however difficult to obtain and almost no information is available from Norway. In collisions with vehicles, older pedestrians also sustain more and more severe injuries than younger pedestrians, especially at higher vehicle speeds.

Adjusting the environmental conditions to the requirements of older pedestrians and improving health and mobility on a broad basis are the most promising safety measures for older pedestrians.

At least three types of measures can be considered for improving the safety of older pedestrians: Measures that directly address older people, measures that address the (environmental) walking conditions for older people, and post-accident measures.

Measures that directly address older people are less likely to be successful when they address specific functional impairments. Almost none of the factors that are commonly assumed to be related to increased injury risk among older pedestrians have been found to be related to actual injury risk. In order to address the more complex risk factors that are related to accident risk, more complex measures are required. Examples are falls prevention programmes and other programmes that increase physical activity. Thereby physical and cognitive skills that are relevant in traffic can be maintained and improved, and vulnerability may be reduced due to increased fitness. Such programmes may also include training programmes for specific skills such as attention, or assist in finding adequate compensation strategies for decreased skills such as impaired vision or walking difficulties.

Other measures that reduce injury risk among older pedestrians are practical aids such as appropriate footwear, anti-sliding devices for shoes (spikes), orientation aids in unknown areas which reduce attention demands. Older people who are especially at risk of falling accidents also may benefit from hip protectors.

The environmental walking conditions for older people can be improved by

- reducing the complexity of road crossings, e.g. median islands, signal phases for turning traffic,
- increasing the available crossing time for pedestrians, e.g. longer signal phasing or puffin signals,
- improving road maintenance and winter maintenance in order to reduce obstacles and slipperiness,
- speed reducing measures in traffic environments that are used by motorized and non-motorized traffic,
- improving pedestrian protection in vehicle design.

Most of these measures additionally increase the accessibility for older pedestrians who have difficulties with walking, and may therefore also have favourable effects for mobility and, consequently, health. Positive effects on physical activity and mobility can also be expected from other measures that make walking more attractive.

Post accident measures that are likely to be favourable especially for older people are devices that facilitate contact with medical services (mobile phones or special devices). Such devices may also reduce anxiety while walking. Rehabilitation programmes for older people that include both physical and motivational training components have been found to reduce the probability of complications, re-injuries, pain and loss of mobility. Thereby, rehabilitation may considerably improve the quality of life of injured older pedestrians.

The social and health effects of pedestrian safety measures are greater when injury risk among older pedestrians is reduced, compared to measures that only address younger pedestrians.

Older people are less resistant to injuries than younger people, and injuries are often more severe, more long-lasting, and have more consequences for quality of life. Measures that reduce injury risk among pedestrians can therefore be expected to have larger positive health effects among older people than among younger people. Additionally, injuries may lead to vicious cycles of reduced mobility and increased (re-) injury risk. Once mobility is reduced after an injury, physical activity decreases, and reduced physical activity leads to further impairments, increased vulnerability, and reduced quality of life.

When measures that reduce injury risk, also make walking more attractive (or less impossible) for older people, still larger health effects can be expected. Increased physical activity reduces accident and injury risk because mental and physical abilities are better maintained, and vulnerability reduced. Additionally, physical fitness and wellbeing increase.

Pedestrian safety measures have different effects on safety, mobility and quality of life among older and younger pedestrians and the values and socioeconomic effects of these effects are different.

The socioeconomic effects of measures addressing especially older pedestrians can be assumed to be different from the socioeconomic effects of other pedestrian safety measures. Quantifying these effects is however difficult, and economic values are not available for a number of aspects that are relevant for older pedestrians. Available values are identical for all groups of road users or for all age groups, although there may be differences between older and younger pedestrians.

If the safety effects on the whole will have larger or smaller economic values is difficult to estimate. Medical costs are often higher for older people and welfare loss due to injuries is also likely to be larger because older people are more vulnerable, and injuries are often more long lasting and may have stronger effects on the quality of life. Property damage, productivity loss and travel delays on the other hand are smaller in pedestrian accidents than in other accidents. Feelings of discomfort or insecurity are only seldom included in socio-economic analyses. Effects on such aspects may be larger among older pedestrians. Effects on mobility may also be larger for older pedestrians than for younger pedestrians. Travel times are likely to be less relevant for older pedestrians because of more recreational trips and fewer work related trips. Different trip purposes are however not taken into accounts in the values of travel times. Travel distances and obstacles may be far more relevant for older pedestrians than for younger ones. Effects on mobility, health and quality of life are difficult or impossible to evaluate. Such effects are complex, and values are not always available.

1 Background and research problem

The aim of this report is the identification of factors that are associated with the risk of older pedestrians and measures to reduce injury risk for this group of road users.

The report is a follow-up of the Report ”Making Vision Zero real: Preventing pedestrian accidents and making them less severe” (Erke & Elvik, 2007) in which risk factors and safety measures for pedestrians and cyclists are summarized. It is based on analyses of Norwegian accident statistics, a literature search among recent studies on accident risk and mobility of older pedestrians and on recent reviews of the literature on the safety of older pedestrians (Dunbar et al., 2004; Dobbs, 2005; Oxley et al., 2004; Sagberg & Glad, 1999).

The report focuses specifically on the safety of older pedestrians and addresses mobility and health effects of walking among older pedestrians. General aspects of pedestrian safety are not taken into account. Special aspects of disabled (older) people are not considered either. The following questions are addressed in the report:

- Who are “older pedestrians” and what are differences between older and younger pedestrians that are relevant for injury risk in road traffic?
- Which types of accidents and injuries are most frequent among older pedestrians?
- Which safety measures address risk factors, accidents and injuries among older pedestrians? Are there measures that focus explicitly on older pedestrians?
- What social and health effects can be expected from injury risk in road traffic among older pedestrians and from measures that reduce injury risk?
- What socioeconomic effects can be expected from measures that reduce injury risk in road traffic among older pedestrians?

2 Older pedestrians: Definitions and characteristics

This Chapter addresses the questions how “older pedestrians” can be defined and what differences between “older” and “younger” pedestrians are relevant for their injury risk in road traffic.

2.1 Who are “older” pedestrians?

There is no generally accepted definition of “older” pedestrians, nor of “older” people in general. The age from which on pedestrians (or other road users) are classified as “older” varies. Examples of definition criteria for “older” or “elderly” pedestrians are above 60 years (Dunbar et al., 2004), above 65 years (Zegeer et al., 2005) or above 70 years (AASHTO, 2004). Research indicates that fatality risk increases from the age of ca. 60 years, and that increase becomes more pronounced from the age of ca. 70 years (Dunbar et al., 2004). The World Health Organization frequently refers to people above 65 years as “older people”.

With increasing age, a number of cognitive, perceptive and physical functions that are relevant to safe traffic behaviour, are deteriorating. However, the changes are complex, variable across time and different between different individuals, and not necessarily noticeable or even large. Chronological age is correlated with such changes and a convenient measure, but correlations are at best moderate and chronological age is by no means useful as an explanatory variable for accident or injury risk (Dunbar et al., 2004). It has also been speculated that the increase in accident risk is smaller than might be expected based on the functional impairments in older people (Dobbs, 2005). A likely explanation is that a decline of physical or mental abilities to a certain degree can be compensated, or even more than compensated. Compensation mechanisms are for example

- more careful behaviour (e.g. walking more slowly), increased attentiveness or choice of routes, crossing facilities etc.
- reduced exposure, i.e. less walking or less walking under conditions which are experienced as unsafe (e.g. complex situations, dark),
- use of helping devices, e.g. hearing aids or walking aids.

It is therefore not surprising that clear associations between age-related declining physical, perceptual or cognitive functions and accident or injury risk seldom are found. According to Oxley et al., (2004) the “older road user problem” is mostly related to subgroups of people who have impairments due to illness or who do not adequately adjust their behaviour to changing abilities. These will be discussed in more detail in the following sections.

2.2 Functional and behavioural changes

The effects of functional and behavioural changes in older people on accident and injury risk has mainly been studied among older drivers. Many of the results are likely to be valid for pedestrians as well, but little research is available to prove this. Furthermore, many studies have methodological weaknesses, and only few studies find strong and unequivocal relationships between functional limitations and accident or injury risk (Oxley et al., 2004).

Several factors may contribute to difficulties in finding relationships between functional impairments and pedestrian safety at increasing ages: Older pedestrians often adapt their behaviour in many ways to (subjective) impairments, and subjective impairments are not always identical with objective impairments (see Section 2.5). Attitudes towards safe traffic behaviour may change as well. Existing relationships may be disguised within larger populations because they become evident only when threshold values are passed. Relationships would then only become evident when extreme group comparisons are made, or when only subjects who have passed the thresholds are studied. Finally, older people become more vulnerable to injury, and injury outcomes are therefore combined effects of accident involvement and vulnerability.

Despite these difficulties, the following sections summarize findings about changes in older people that are (or that may be) relevant for accident and injury risk while walking.

2.2.1 Visual perception

Relationships between visual perception abilities and injury risk in road traffic has mostly been studied among drivers. The most part of information that is required for driving is visual information. Visual functions that are decreasing with age are visual acuity, contrast sensitivity, peripheral vision, resistance to glare, and low luminescence vision (Dobbs, 2005). These changes may be due to normal physiological changes or to pathological changes.

According to the literature review by Dobbs (2005), most studies that have investigated the relationships between visual (static) acuity or contrast sensitivity and driving performance or accident risk have found no or only weak relationships. Among the possible reasons are methodological weaknesses of the studies (e.g. lack of reliability and validity of the tests used). It is also likely that visual impairments to a large degree can be compensated by behaviour adaptation (e.g. not driving in the dark, driving only known routes where no signposts have to be read).

Studies that have investigated dynamic visual acuity have found this to be a reliable predictor of accident risk for car drivers (Fox, 1989; Graca, 1986). Dynamic visual acuity is the ability to resolve the details of an object while there is relative motion between the target and the observer. Peripheral vision, night-time vision and active visual search have also been identified as factors that deteriorate with increasing age and that affect accident risk among drivers (Dunbar et al., 2004).

These studies have studied only older drivers. Pedestrians also need visual information for walking (safely). Studies have shown that visual impairments increase the risk of falling accidents (Dunbar et al., 2004). No studies have been found on the effect of visual impairments on other types of pedestrian accidents.

2.2.2 Auditory perception

The prevalence of hearing problems is increasing almost linearly with increasing age. In the age group 18-34 only ca. 3% have hearing problems and among people 65 years and older ca. 30% have hearing problems (Dobbs, 2005). The proportions with hearing problems is larger and hearing declines more rapidly among men than among women. However, consistent relationships between hearing and driving abilities, or between hearing and accident risk among drivers or pedestrians have not been found (Dobbs, 2005; Dunbar et al., 2004). It seems reasonable to assume that decreased hearing abilities can, at least to a large degree, be compensated by increased attention (more active visual search) and modified behaviour (e.g. avoiding situations where traffic may be approaching from behind).

2.2.3 Cognitive performance

Cognitive performance is not generally decreasing with increasing age. Some aspects are however declining. Central processing speed is reduced with increasing age, and there may be a reduction in available resources such as attention (Dunbar et al., 2004). The result is often a slowing down of sensation, perception, cognition, reaction times and motor response times, and a generally slowed conversion of perception and judgement into action (Dobbs, 2005; Oxley et al., 2004). These deficiencies are often and in many aspects of daily life compensated.

Other aspects of cognitive performance increase with increasing age. Increasing age is for example associated with increasing knowledge and experience. Attitudes and lifestyles may also change.

Performance in traffic environments may be impaired by some of the declining processes because of the often required quick reactions and the speed and amount of information that has to be processed. The most frequent problems that arise because of changes in cognitive performance are problems in complex situations which require reactions on rapid changes (Rytz, 2006; see also Section 2.2.4 Attention).

Increasing age leads often to a reduced ability to judge the speed of motor vehicles. Mostly speed is underestimated and time to collision is overestimated (Oxley et al., 2004; Wilton & Davey, 2007). These misjudgements contribute frequently to difficulties with gap selection. Additionally, risk perception may be reduced with increasing age (Oxley et al., 2004).

These problems are largest in complex environments such as multilane roads or intersections where approaching vehicles from different directions have to be paid attention to, and when vehicle speeds are high.

Pathological processes, such as the onset of dementia, are also likely to impair pedestrian performance.

Among older drivers there are several traffic violations that frequently lead to accidents. These are, amongst others, red light violations, unsafe left turns, unsafe passing, and failure to yield. Such violations may however be due to an "obedience problem" rather than to decreasing cognitive abilities (Dobbs, 2005).

2.2.4 Attention

Attention is a complex phenomenon and not all aspects of attention differ between older and younger adults. Scanning the environment for clues and sustained attention are for example not systematically changing with increasing age.

On tasks with high attention demands and on tasks with demands on selective or divided attention, differences are frequently found between younger and older people. Older people are also performing more poorly on tasks requiring attention to changing objects and prioritizing information. Differences between old and young adults are most pronounced on complex tasks and on tasks requiring quick responses (Dobbs, 2005; Dunbar et al., 2004).

Being pedestrian is in many situations associated with high attention demands, e.g. when crossing roads or in intersections. There is according to Dunbar et al. (2004) evidence that attention deficiencies in older people is related to poorer driving performance, to unsafe pedestrian behaviour, and to increased risk of falling accidents. Poor performance on attention demanding tasks is therefore likely to be a contributing factor to the increased accident risk of older pedestrians especially at intersections.

An aspect of attention for which a relationship with accident risk is well documented is the useful field of view, i.e. the field over which information can be perceived during a brief glance. Preconditions are divided attention, selective attention and perceptual speed. The useful field of view can be improved by training, but it has not been studied to what degree training may contribute to reducing accident risk (Sagberg & Glad, 1999).

When there are deficiencies in attention, more attentional control is required on tasks that are largely automatic among younger people, such as walking. This reduces the amount of cognitive capacity that is available for other tasks. Reactions to other attentional demands from the traffic environment may therefore cause problems, especially when responses to rapid changes are required.

2.2.5 Physical abilities

Physical abilities are decreasing with increasing age. Relevant changes for pedestrians are mainly reduced walking speed, reduced ability to coordinate movements with changing visual inputs, reduced strength and reduced balance. This reduces the possibilities for quick evasive actions (Oxley et al., 2004), and increases attentional demands as compared to younger people for whom walking is mostly automatic and usually does not require much attention (see Section 2.2.4). Additionally, difficulties with walking, especially balance problems, are associated with cognitive and other functional impairments (Dunbar et al., 2004). Reduced walking speed increases exposure, i.e. lengthens the time that is spent for example crossing roads, and leads to larger gaps in approaching vehicles.

Walking speed is reduced most among older pedestrians suffering from some illness. For these pedestrians, measures such as longer green signals may not be sufficient (Dunbar et al., 2004).

General difficulties with walking are reported increasingly at older ages. In a study from the US, 32% of older people reported health as an obstacle to walking (Dunbar et al., 2004). In a British study, 50% of men and 70% of women above 80 years reported problems and could not walk outdoors without help or at least not without difficulties (Dunbar et al., 2004). In addition to decreasing physical abilities, vulnerability is increasing (see Section 2.5).

2.3 Diseases

A number of diseases may contribute to increased accident risk among older pedestrians. Most research has been conducted on the effects of diseases on driver behaviour and accident risk among drivers. Only little research is available that specifically addresses pedestrians. Research indicates that the effects of diseases vary individually. The resulting functional capability is more important for accident risk than specific diseases. Older people who already are suffering from functional impairments may be more impaired by a disease than people who are not suffering from other functional impairments. Several diseases may lead to larger functional impairments than the sum of the impairments that are caused by each of the diseases (Dunbar et al., 2004).

Many diseases are likely to restrict and reduce the mobility of older people and risk assessments can therefore be biased when exposure is not controlled for.

Cardiovascular diseases

The prevalence of coronary artery diseases increases with increasing age from ca. 2% in the age group 25-34 years to ca. 15% in the age group above 75 years. Coronary heart diseases may cause safety problems (“sudden death at the wheel”), but these are very rare events (Dobbs, 2005).

Hypertension is associated with impaired cognitive performance. This is likely to lead to safety problems (Oxley et al., 2004), but according to the literature review by Dobbs (2005) there not enough data available to find relationships with the risk for road accidents. Hypotension also may lead to safety problems (periods of unconsciousness), but these are also very rare events.

Cerebrovascular diseases, stroke

A stroke may lead to other medical conditions that may cause safety problems, e.g. a wide range of cognitive impairments. The consequences of a stroke vary individually and no general conclusions about the safety impacts of stroke can be drawn (Dobbs, 2005).

Metabolic diseases

Diabetes mellitus has a larger prevalence with increasing age. It may lead to hypoglemic reactions which may lead to a number of autonomic symptoms and cognitive dysfunction. While some studies have found increased accident involvement among drivers with diabetes mellitus, other studies have not found any relationship (Dobbs, 2005).

Hyper- and hypothyroidism also have larger prevalence with increasing age and may lead to cognitive impairments which may lead to safety problems (Dobbs, 2005).

Musculoskeletal disabilities

Musculoskeletal impairments increase with increasing age and may contribute to increased accident risk among older pedestrians (Oxley et al., 2004). Causes may be arthritis, rheumatism, back problems, heart trouble, respiratory diseases, hypertension, diabetes or stroke, amongst others (Dobbs, 2005). In an older study from the US (Cormoni-Huntley et al., 1986) 32% of males above 65 and 48% of women above 65 years reported gross physical dysfunction (inability to walk half a mile or to climb stairs).

Psychiatric diseases

Psychiatric diseases may reduce cognitive abilities. There are few studies that have investigated the relationship with road safety. Increased accident risk has been found among persons with psychiatric diseases such as personality disorders, psychotics, alcoholics, and schizophrenia (Dobbs, 2005). The results may however be biased by methodological weaknesses, and exposure among people with psychiatric diseases is likely to be substantially lower than for people without psychiatric diseases. Suicidal motivation may also be one of the contributing factors to increased accident risk, but this may be less relevant for pedestrians than for drivers of motor vehicles.

Dementia

Dementia is likely to be associated with increased accident risk. However, according to Oxley et al. (2004) almost nothing is known about the effects of dementia on exposure (amount of walking) and on accident risk among pedestrians.

2.4 Medication

According to the literature surveys by Oxley et al. (2004) and Dobbs (2005), drivers under the influence of drugs (pharmaceuticals) are overrepresented among older drivers. People above 65 years are according to studies from the US using more than twice as much pharmaceuticals as younger people. Many of these impair cognitive performance, for example analgesics, antidepressants, and antihistamines. Older people use more frequently several drugs simultaneously, which leads to greater impairments than the sum of the impairments caused by each of the drugs. Additionally, older peoples’ reactions to medication are often different (stronger) from younger peoples reactions.

2.5 Vulnerability

Older people who are involved in an accident are more vulnerable than younger adults. They are more likely to sustain fractures, they need more recovery time and they are more likely to be permanently disabled. For pedestrians who are injured in a road accident the risk of being killed is larger for older than for younger pedestrians. The risk of sustaining permanent injuries is also larger among older pedestrians (Oxley et al., 2004). The risk of sustaining injuries in falling accidents increases with increasing age because of higher risk of falling and less robust bone structure. The risk of sustaining injuries in falling accidents increases still more for pedestrians who have had previous falling accidents (Eilert-Petersson & Schelp, 1998).

The psychological consequences of accidents for older pedestrians have not been studied, but according to Dunbar et al. (2004) they are likely to be serious, may increase anxiousness and consequently reduce mobility and the associated positive health effects.

2.6 Behaviour and compensation

Many studies have found that older pedestrians use a number of mechanisms for compensating declining abilities. Compensation mechanisms are for example avoiding difficult situations or unfamiliar locations, slower walking, or using more time to observe traffic. While crossing roads, older pedestrians are more cautious, keep longer distance from kerbs, look more carefully and desire longer gaps between approaching vehicles than younger pedestrians. In some cases they overcompensate e.g. by selecting extra-large gaps in approaching traffic while crossing roads. Older pedestrians are less likely than younger pedestrians to have been drinking while walking (Dunbar et al., 2004).

In total however, the increasing accident risk at older ages indicates that compensation in many cases is not sufficient. In some cases compensation even increases risk. Gap acceptance is often based on distance rather than speed and does not always fully take into account the own walking speed. This may lead to the acceptance of inadequately short gaps, especially when vehicle speeds are high. Longer distance from kerbs and hesitating before crossing increase crossing times. Many older pedestrians use younger pedestrians (especially well dressed ones) as role models and follow them, for example while crossing roads. When differences in walking speeds are disregarded or when traffic observation is neglected, dangerous situations may arise (Dunbar et al., 2004).

Compensation for functional impairments has certain limits, strong or multiple impairments are for example more difficult to compensate. Compensation is also dependent on a realistic self-assessment. Research has shown that self-assessment of functional impairments is not always correlated with objective functional impairments and not always focused on relevant aspects of impaired functions. Older pedestrians focus for example much on hearing problems, which does not seem to affect pedestrian safety (however, this may be due to just this high focus on hearing problems among older pedestrians). Older people are more inclined to overestimate own abilities than to underestimate them (Rytz, 2006). Reasons for overestimating own abilities may be previous accident history and the slow onset of physical impairments and diseases at older age. Compensation by choosing safer routes (e.g. avoiding complex situations) is often an unattractive alternative for older pedestrians because it would require detours which most older pedestrians are not very fond of (Rytz, 2005).

The awareness of decreasing perceptual and cognitive functions and the ability to judge own abilities and risk perception decrease with increasing age (and increasing functional impairments). There is a lack of insight especially for decreasing cognitive functions (Dunbar et al., 2004). This limits the likely amount of successful compensation at older ages, when it would be most useful.

Self-awareness of functional impairments can be improved by good environmental feedback. There is however need for more research on how self-assessment can be improved by environmental feedback and how effective feedback can be provided (Dunbar et al., 2004).

A study from Switzerland (Seeger, 2005) found that the main contributing factors in most accidents which were caused by older drivers, were medical conditions and not non-pathologically impaired functions due to old age. Most older drivers who are not suffering from diseases, are likely to be able to compensate for functional impairments.

2.7 Demographics

The proportion of older people is likely to increase in future years. The structure of the Norwegian population in 2005 and the estimated structure of the Norwegian population in 2060 are shown in Figure 2.7.1 and 2.7.2. The proportion of people above 66 years in 2005 was 13.1%. The proportions of people above 66 years that are estimated, based on different scenarios, are likely to increase steadily in the next ca. 50 years as shown in Figure 2.7.3.

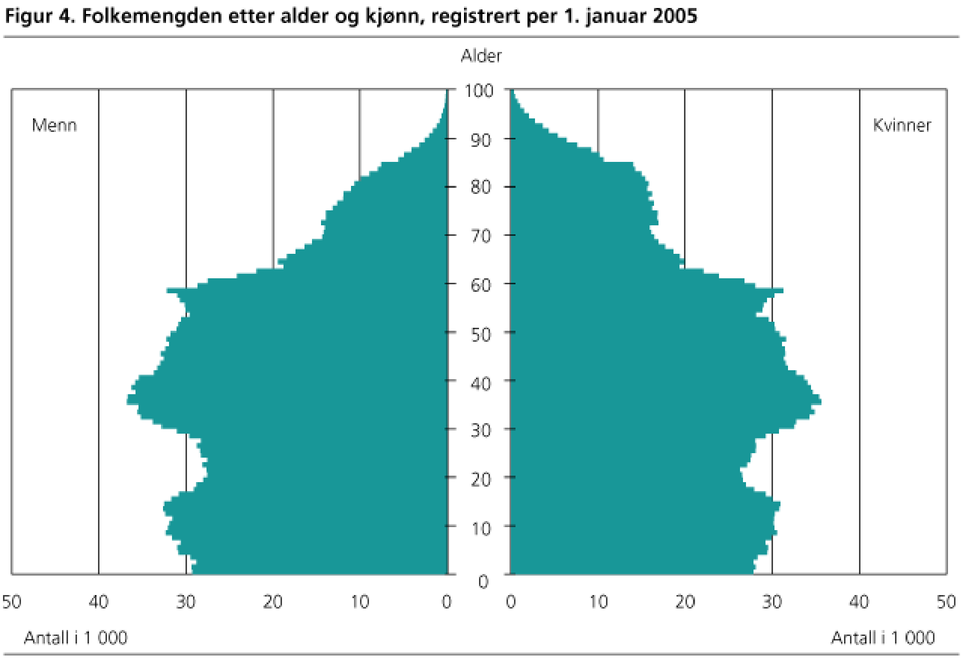

Figure 2.7.1: Population in Norway, age and gender, 2005 (SSB).

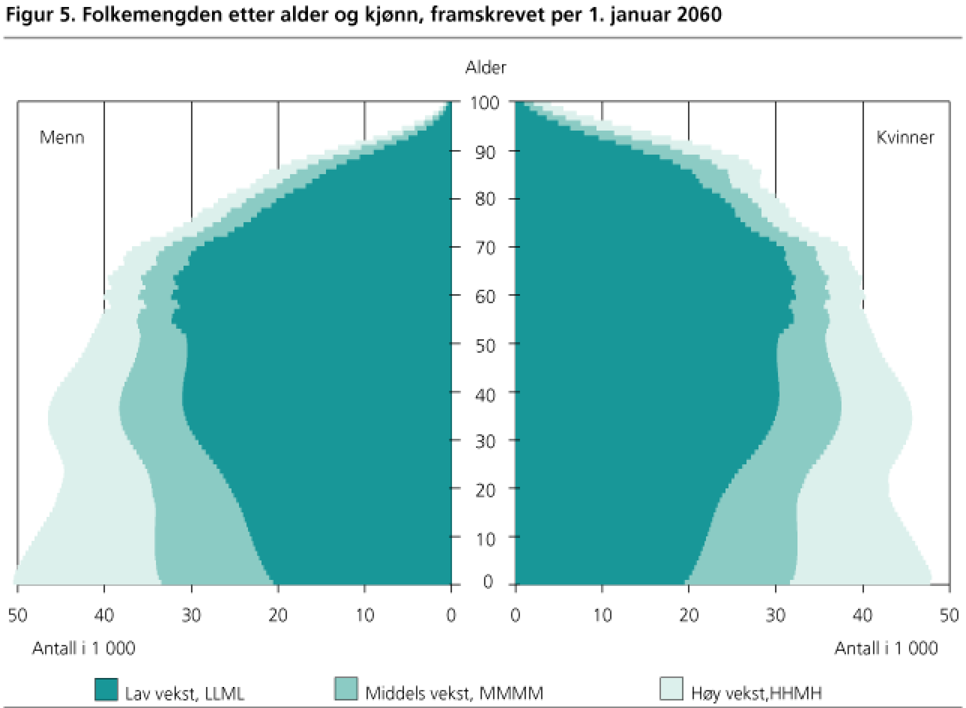

Figure 2.7.2: Population in Norway, age and gender, estimated in 2060 (SSB).

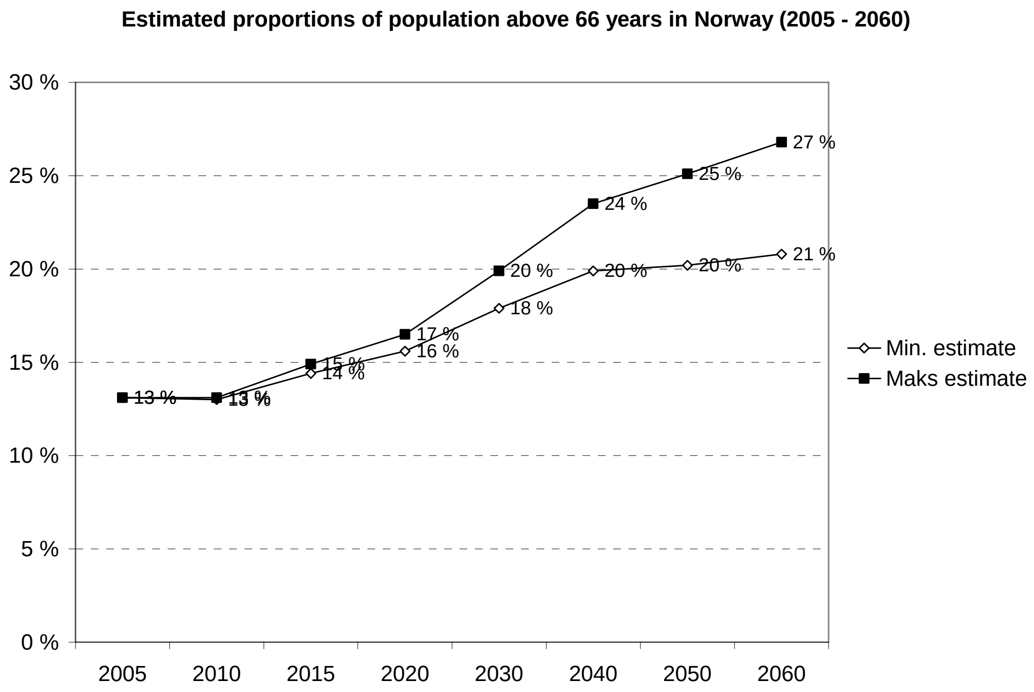

Figure 2.7.3: Proportions of population above 66 years in Norway, estimated min. and max proportions (SSB).

3 Older pedestrians in Norway: Mobility and injury risk

This Chapter addresses mobility, accidents and injuries and risk factors among older pedestrians in Norway. It investigates walking habits in the (older) Norwegian population and the question under which circumstances most accidents and injuries among older pedestrians occur in Norway. Many of the results no not say much about accident or injury risk because exposure data only are available on a very general level. It is for example not known how many kilometres are walked in the dark or how many roads are crossed by older pedestrians.

3.1 Mobility: Walking

3.1.1 Total amount of walking

The total amount of walking in 2001 and 2005 has been estimated by Bjørnskau (2003; 2008) for men and women in different age groups (figures 3.1.1 and 3.1.2).

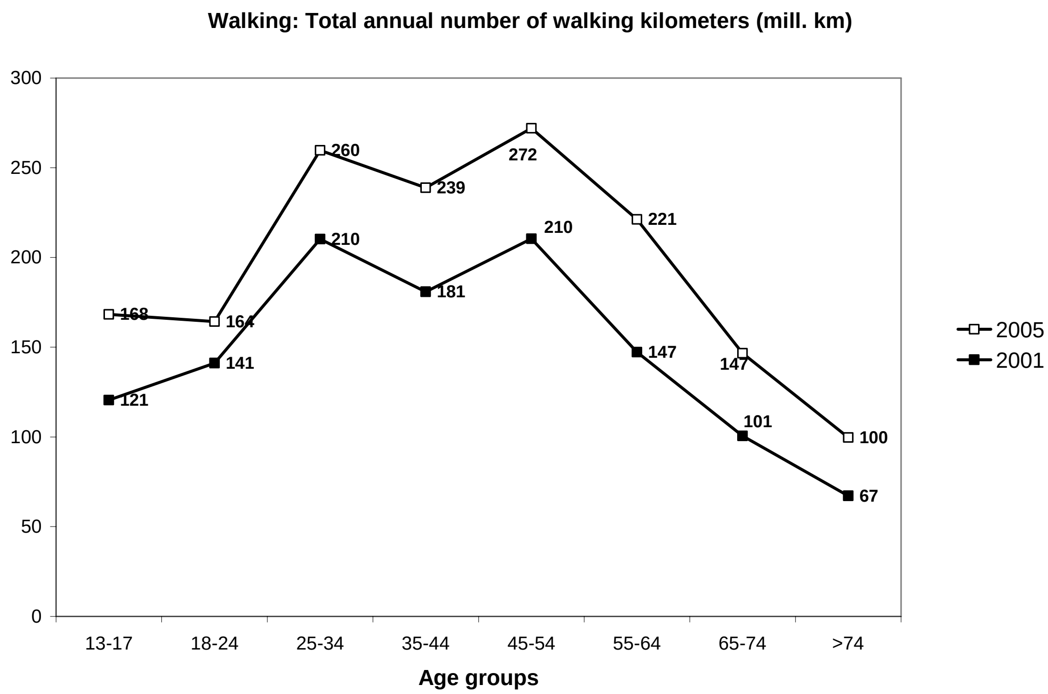

Figure 3.1.1: Total amount of walking in Norway 2001, 2005 (Bjørnskau, 2008).

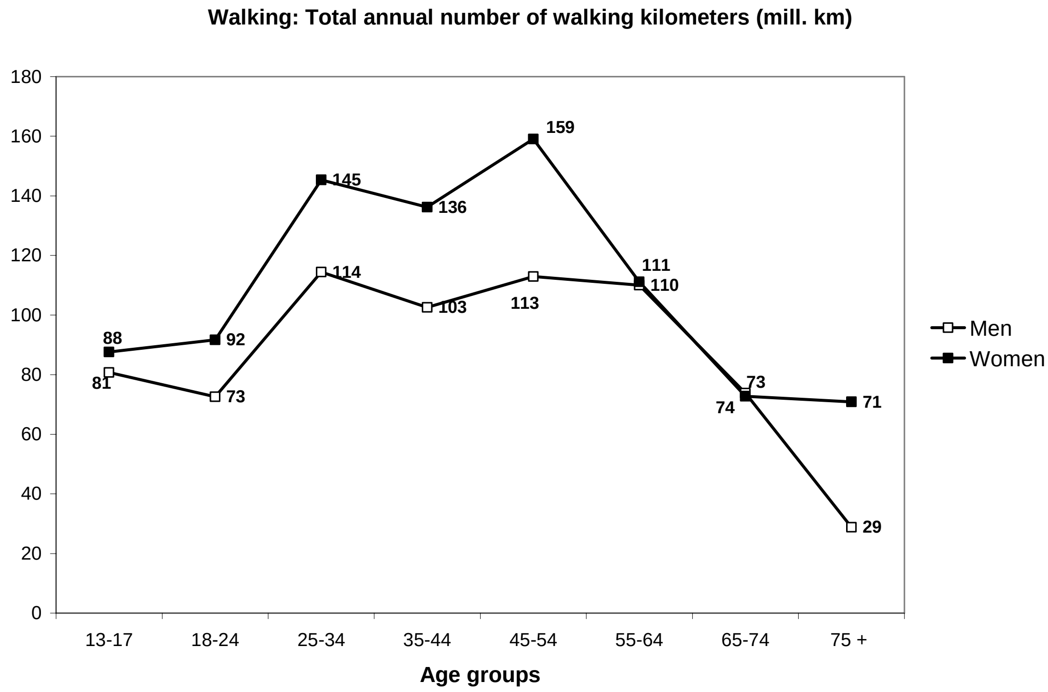

Figure 3.1.2: Total annual amount of walking in different age groups, million walking kilometres, men and women (2005; Bjørnskau, 2008).

3.1.2 Walking trips and walking habits

Individual walking trips and walking habits have been investigated in the Norwegian Travel Survey (Vågane, 2006). The proportion of persons who have been walking during the day before the interview and the average trip lengths among those who had been walking are shown in table 3.1.1. The proportion of persons having walked is almost constant in all age groups above 25 years. The shortest trips have been walked in the youngest age groups. The longest trips have been walked in the age groups 45 – 54 and 55 – 66 years. In older age groups trip length decreases with increasing age. In other countries, both increasing (Denmark, Netherlands, Switzerland) decreasing (Australia, Great Britain) and constant (Finland) average walking trip lengths with increasing age have been found (Oxley et al., 2004).

From the age of 45 years men (who are walking) are walking longer trips than women. Longer trips at older ages can be due to more recreational walking. Results from the travel survey have shown that purely recreational walks usually are longer than transportation walks and that older people walk more often for recreational purposes than younger people.

Table 3.1.1:Proportions having walked and average walking trip length among those who have walked (Vågane, 2006).

	Proportion having walked	Average trip length among those having walked	
		Men	Women
13 – 17 years	47 %	3.3 km	3.2 km
18 – 24 years	38 %	3.0 km	3.1 km
25 – 34 years	34 %	3.3 km	3.4 km
35 – 44 years	28 %	3.2 km	3.6 km
45 – 54 years	31 %	4.0 km	3.9 km
55 – 66 years	30 %	4.4 km	3.4 km
67 – 74 years	33 %	4.1 km	3.1 km
> 74 years	31 %	3.5 km	2.9 km

The proportions of persons who have walked have changed during the last 15 years and the changes are different in different age groups as shown in table 3.1.2. There has been an increase in the middle and younger age groups. The proportion of persons having walked has stayed constant in the age group 67-74 years and has decreased in the age group above 74 years.

Table 3.1.2: Proportions having walked, 1992, 2001 and 2005 (Vågane, 2006).

	1992	2001	2005
25 – 34 years	17 %	19 %	34 %
35 – 44 years	18 %	16 %	28 %
45 – 54 years	18 %	18 %	31 %
55 – 66 years	23 %	20 %	30 %
67 – 74 years	35 %	32 %	33 %
> 74 years	42 %	37 %	31 %

One of the factors that may contribute to the shorter length of the walking trips in the older age groups compared with the younger age groups is that older people generally have more problems with walking than younger people. The Norwegian Travel Survey has shown that there are larger proportions having problems with walking among older than among younger people (table 3.1.3; no results for people under 55 years available). The increase is larger among women than among men. The almost constant proportion of persons who have been walked in all age groups (see above) indicates that the proportion of people walking among those that do not have problems with walking is larger in the older age groups.

Table 3.1.3: Problems with walking among men and women 55 years and older. Source: Vågane (2006).

	Men	Women
55 – 66 years	11 %	17 %
67 – 74 years	19 %	26 %
> 75 years	36 %	56 %

3.2 Accidents and injuries among older pedestrians in Norway

3.2.1 Pedestrian fatalities and injuries

The average annual numbers of fatalities and injuries among pedestrians in different age groups in the years 2001-2005 are shown in Figure 3.2.1. The numbers of fatalities and very severe / severe injuries increases in the oldest age groups. The number of slight injuries decreases in the older age groups up to the age of 65-74 years, and increases again in the age group above 74. These results do however not say anything about the risk associated with walking at different ages. They may as well be affected by demographics (population within each age group, se above section 2.7), by differences in exposure (amount of walking, se above section 3.1.1), and by differences in vulnerability (see below).

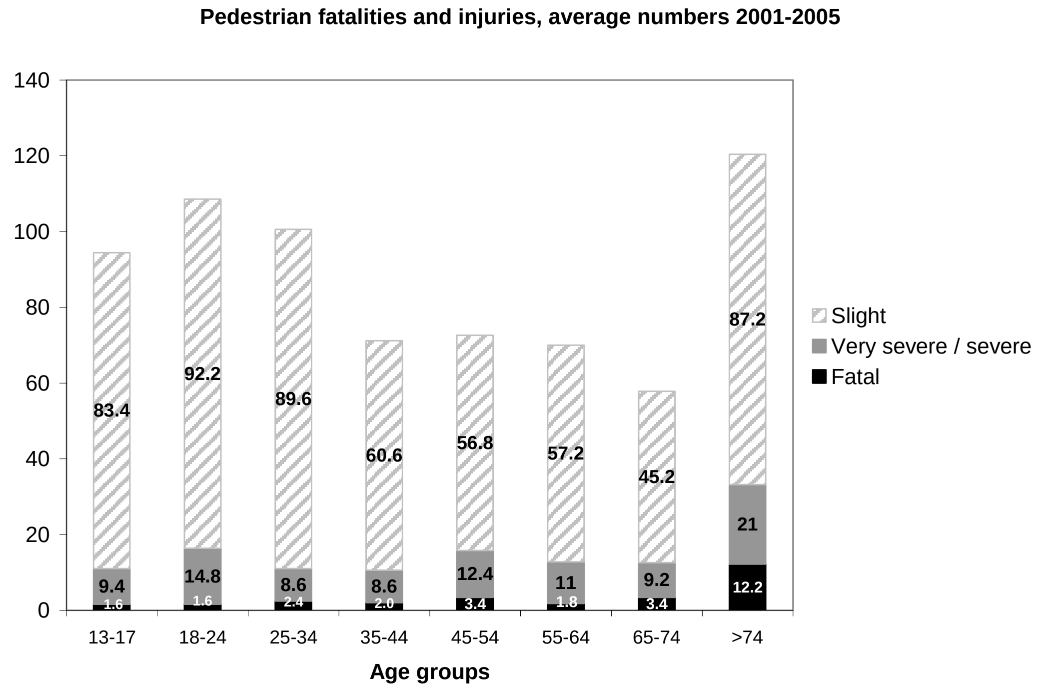

Figure 3.2.1: Pedestrian fatalities and injuries, annual average numbers 2001-2005.

The proportions of fatally, very severely or severely injured pedestrians in Norway (2001-2005) are shown in Figure 3.2.2 for different age groups. The proportion of fatally injured pedestrian increases with increasing age. The largest proportions of fatal, very severe or severe injuries occur in the age groups above 74 years. Compared to pedestrians under 65 years the proportion of fatal injuries is ca. 2-5 times larger than in younger age groups. This corresponds to results from other countries, e.g. Switzerland where the proportion of fatal injuries among all injuries is three times larger among pedestrians above 65 years compared to pedestrians under 65 years (Rytz, 2005).

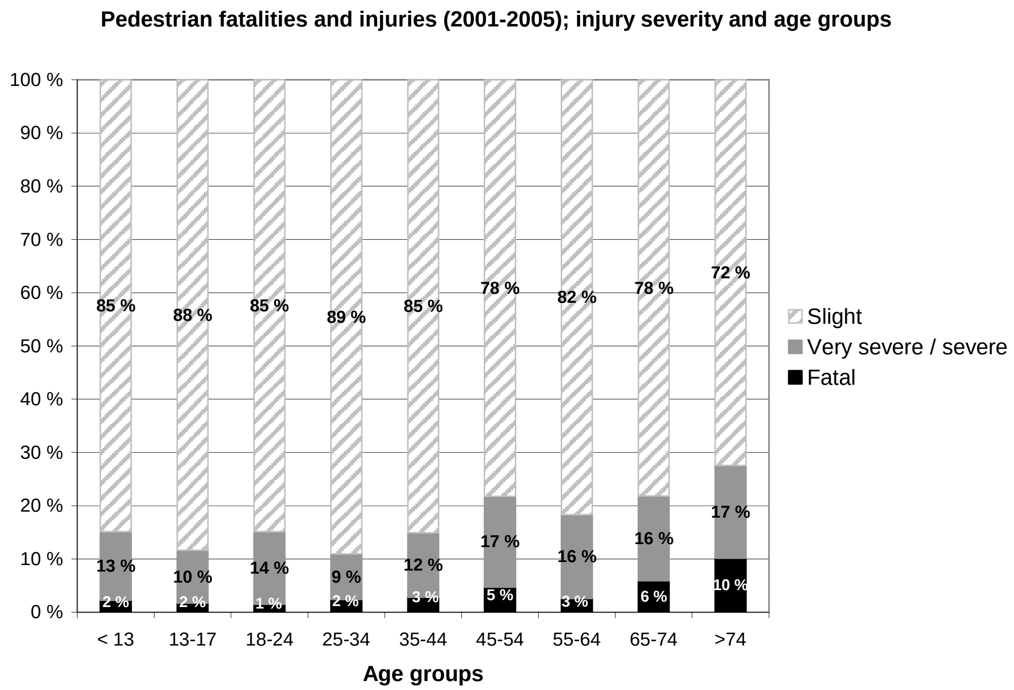

Figure 3.2.2: Pedestrian fatalities and injuries, injury severity and age groups (2001-2005).

In Figure 3.2.3 the relationship between age and the proportion of fatally, very severely or severely injured pedestrians is shown. There is a large amount of random variation in the proportions. The trend functions (polynomial and linear trends) show an increase of the proportion of fatal, very severe and severe injuries with increasing age. Based on these results it is not possible to identify an age or age group where a marked increase in accident severity is noticeable. The increase is continuous and seems to become steeper at older ages. There is however large variation between consecutive years. In these results it is not taken into account that there may be differences between age groups such as different classification of injuries or differences in the probability with which medical treatment is sought or provided with a given injury.

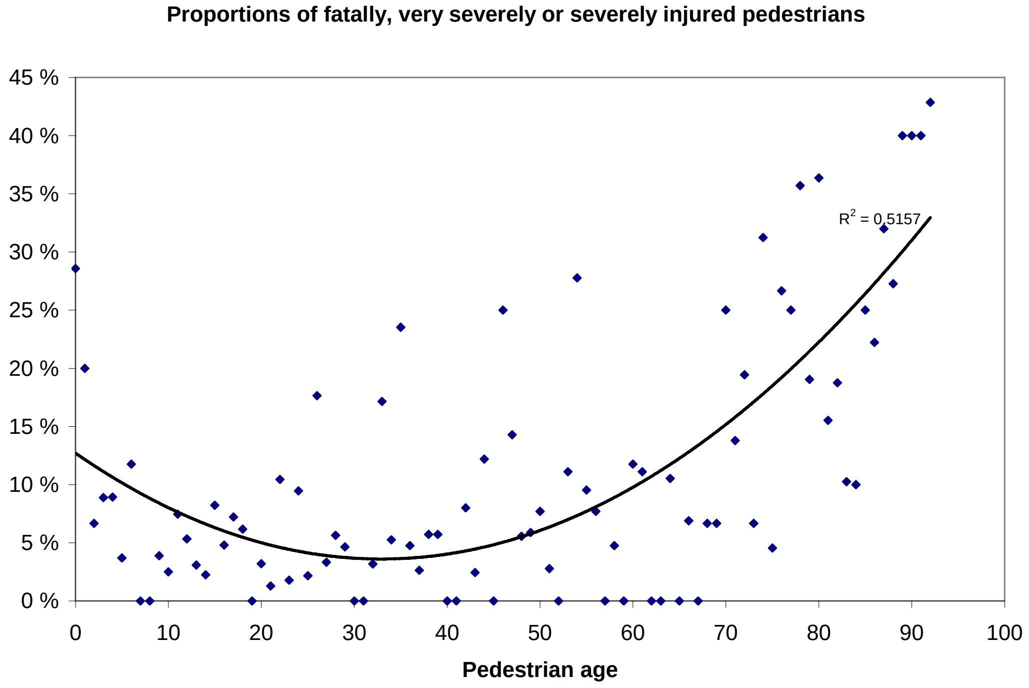

Figure 3.2.3: Pedestrian age and proportions of fatal, very severe or severe injuries (2001-2005).

The proportions of pedestrian fatalities and injuries among men and women in different age groups are shown in Figure 3.2.4. The proportion of women increases in the older age groups.

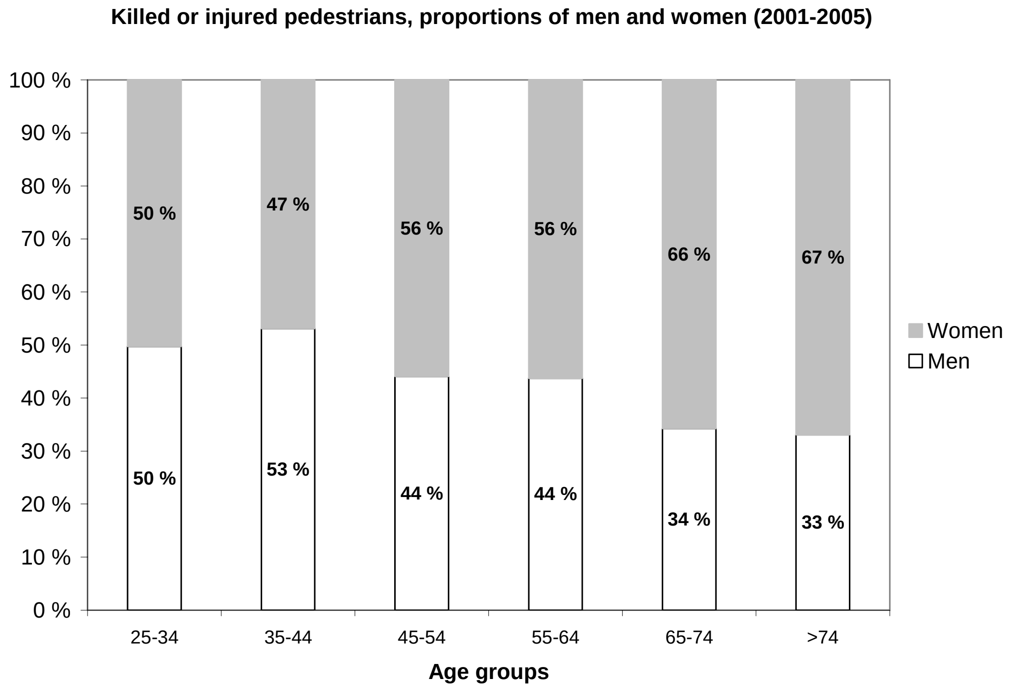

Figure 3.2.4: Killed or injured pedestrians, proportions of men and women (2001-2005).

The proportions of male and female pedestrians that are fatally, very severely or severely injured in different age groups are shown in Figure 3.2.5. The proportion of women increases in the older age groups, similar to the proportion of women among all killed or injured pedestrians. This similarity indicates that accident severity is not changing differently between men and women.

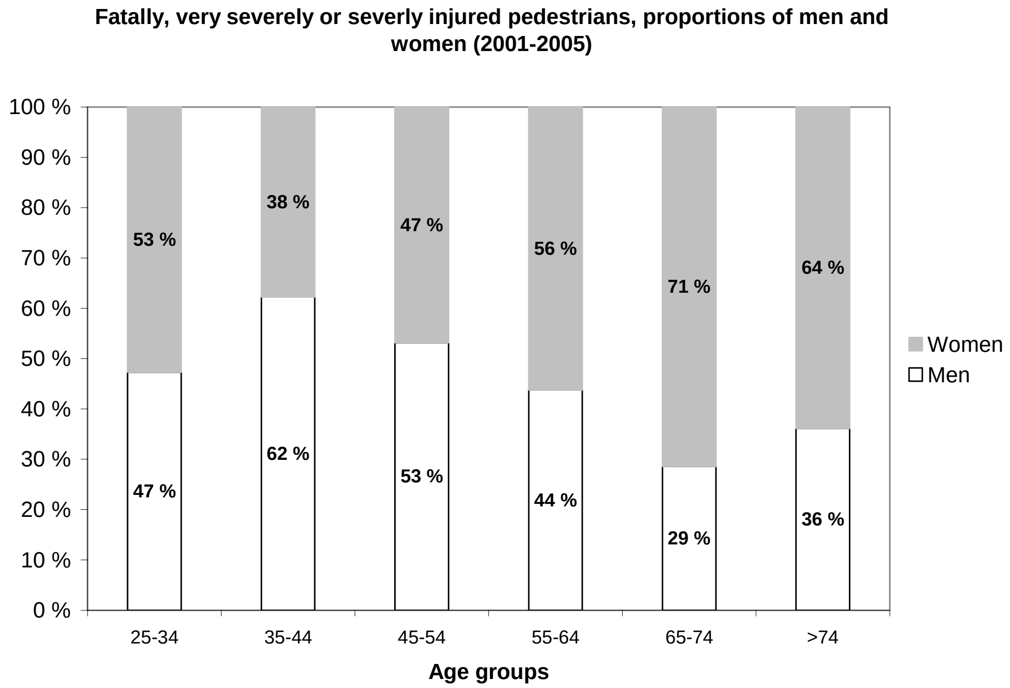

Figure 3.2.5: Fatally, very severely or severely or injured pedestrians, proportions of men and women (2001-2005).

Figure 3.2.6 shows the proportions of pedestrian fatalities and injuries among all road fatalities in Norway (2001-2005). Among adults, the proportion of pedestrians among all injuries increases with increasing age. These results are in accordance with the results from Sagberg & Glad (1999), the proportions of pedestrian injuries among all injuries in road traffic do not seem to have changed significantly in the last 15 years.

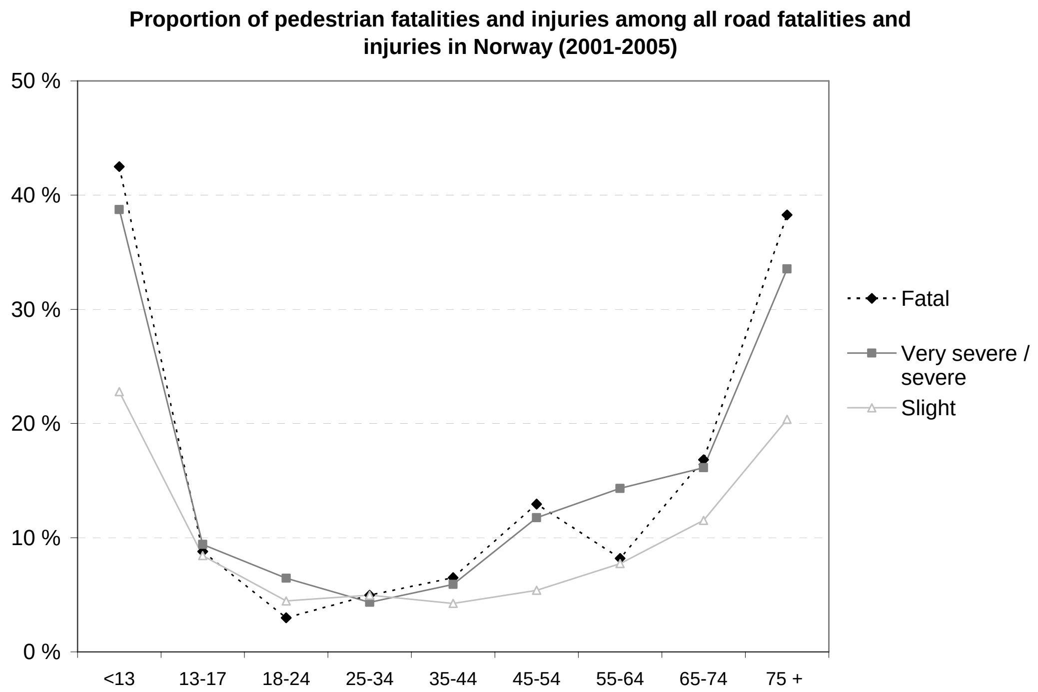

Figure 3.2.6: Proportions of pedestrian fatalities and injuries among all road fatalities in Norway (2001-2005).

According to the literature review by Oxley et al., (2004) increasing accident risk and accident severity is an internationally common phenomenon. The increase of injury risk is most pronounced at more advanced ages and more pronounced for older pedestrians than for older car occupants. According to Oxley et al., the increase in injury risk is mostly due to increasing vulnerability at older ages, rather than increased accident risk.

3.2.2 Fatality and injury risk

The numbers of pedestrian fatalities and injuries per billion walking km in different age groups are shown in Figure 3.2.7. These figures are based on exposure data which have been estimated based on the Norwegian Travel Survey (Bjørnskau, 2008). Injury and fatality risk increase with increasing age from the age of about 55 years. The increase is largest between the two oldest age groups.

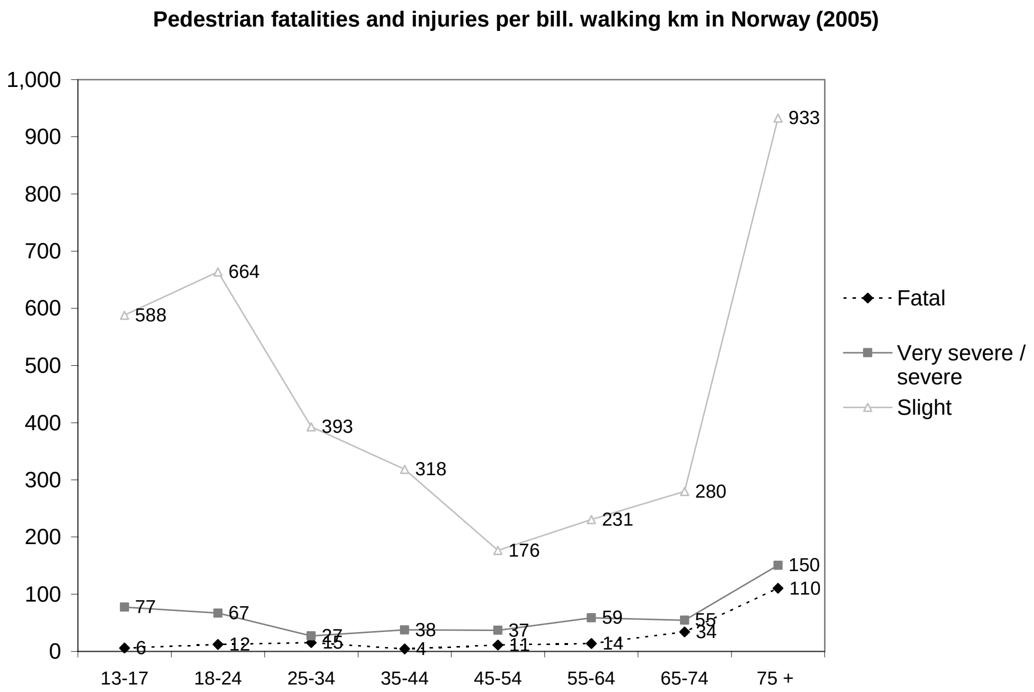

Figure 3.2.7: Fatalities and injuries per billion walking km in Norway (2005; Bjørnskau, 2008; SSB).

Figure 3.2.8 shows the injury risk for male and female pedestrians in different age groups in 2005, as estimated by Bjørnskau (2008). In the age groups above 55 years injury risk is greater among women than among men.

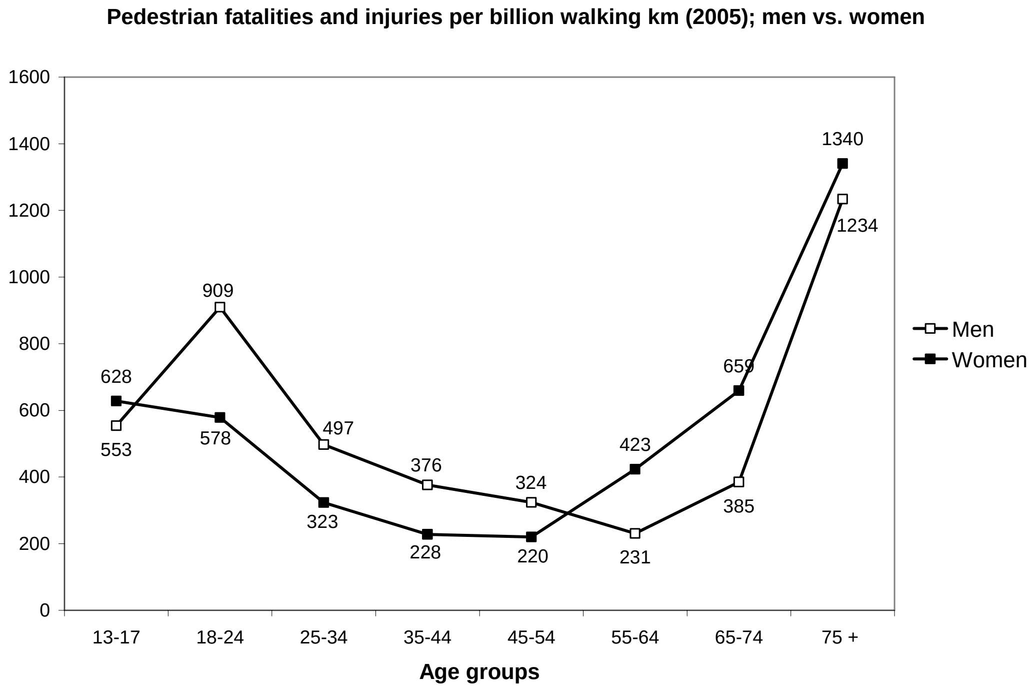

Figure 3.2.8: Pedestrian fatalities and injuries per billion person-km, 2005 (Bjørnskau, 2008; SSB).

The fatality and injury risk relative to the population is shown in figure 3.2.9. The shapes of the curves are similar to those that refer to the injury risk per billion walking kilometres (figure 3.2.7). The increase of the risk per population starts however already from the age of 35 years, most likely because the number of walking kilometres is larger in the middle age groups. Studies reviewed by Dunbar et al. (2004) also have found increased injury risk with increasing age, and a stronger increase at higher ages. The increase of fatality risk in Norway is however moderate compared to the increase that has been reported from other countries. Hagenzieker (1998) reports that average fatality rates in the age groups of between 25-64 years and 65 and older are 0.97 and 8.61 respectively in Denmark, 1.52 and 6.19 respectively in Finland, and 0.97 and 4.48 respectively in Sweden. It is not known to what degree the criteria for including pedestrian fatalities in accident statistics are the same in these countries as in Norway.

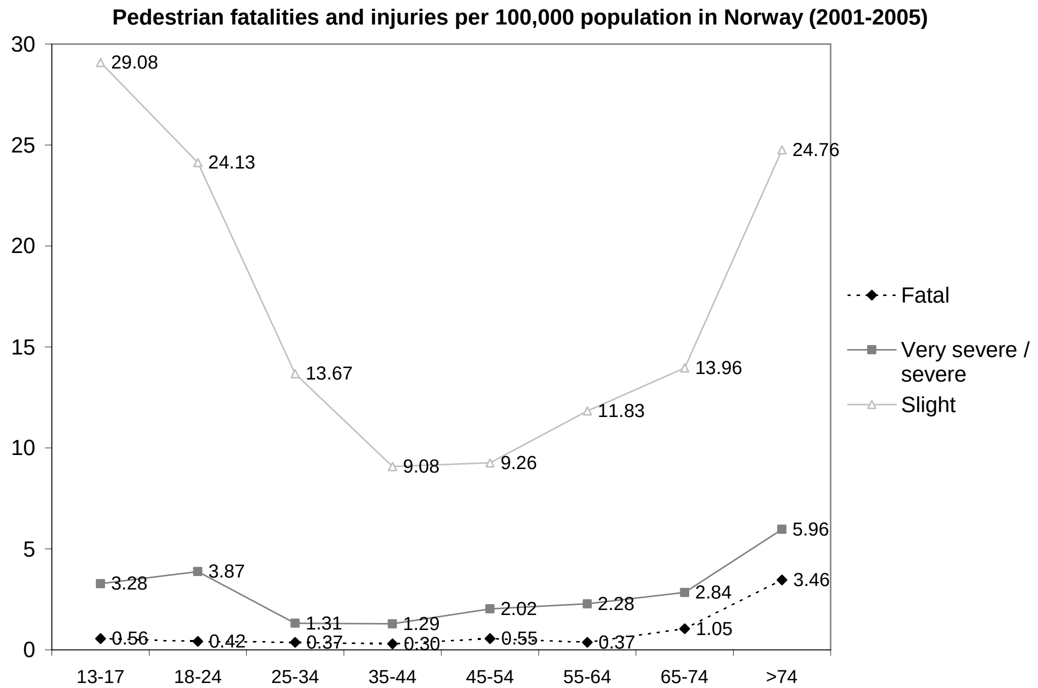

Figure 3.2.9: Pedestrian fatalities and injuries per 100,00 population in Norway (2001-2005).

3.2.3 Comparison of population, total amount of walking and fatality / injury risk between age groups

The proportions of population, total amount of walking, numbers of fatalities and injuries and numbers of fatalities are illustrated in Figure 3.2.10 (population / pedestrians above 13 years). In relation to the proportions of the population, the age group above 75 is underrepresented as regards total amount of walking and overrepresented as regards numbers of fatalities and injuries. The two oldest age groups account for over 50% of all pedestrian fatalities (among those over 13 years). Similar results have been found in other studies. According to AASHTO (2004), older pedestrians (above 70 years) account for 17% of all pedestrian fatalities and 6% of all pedestrian injuries.

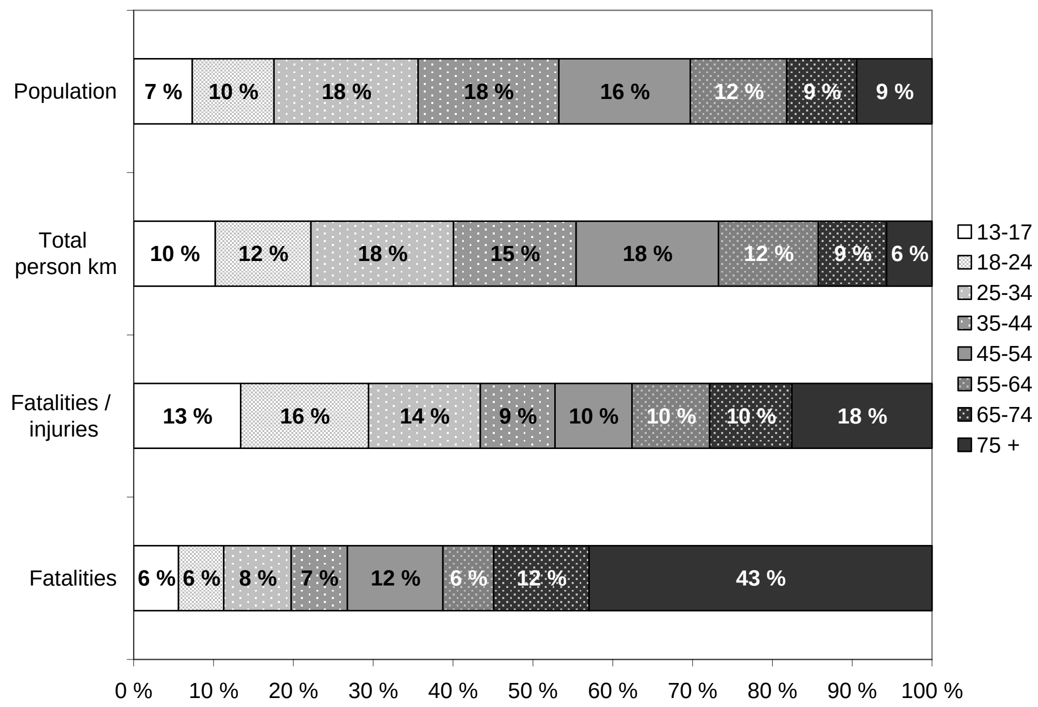

Figure 3.2.10: Proportions of population, total amount of walking, and fatality and injury risk in different age groups (Bjørnskau, 2003; SSB).

3.3 Accident and injury risk factors for older pedestrians in Norway

In this section the relationship between accidents or injuries and several characteristics of accidents are summarized based on accident data from official accident statistics (SSB). Pedestrian accidents are defined as road accidents and included in official accident statistics only when a pedestrian is hit by a cyclists or a motor vehicle. Single pedestrian accidents, i.e. pedestrians falling without any other road user or vehicle being involved, are not defined as road accidents.

3.3.1 Road accident types and locations

The numbers of injured pedestrians in different types of road accidents are shown in Figure 3.3.1 for all injuries (fatal and non-fatal injuries) and in Figure 3.3.2 for fatal, very severe or severe injuries. There are no clearly identifiable trends of increasing or decreasing proportions of specific types of accidents with increasing age.

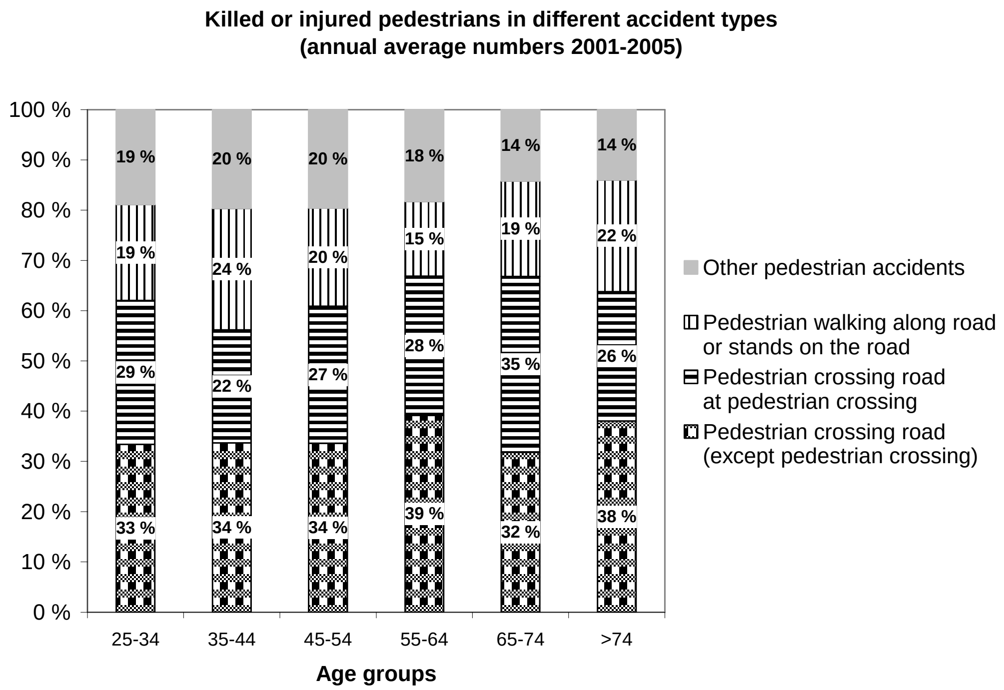

Figure 3.3.1: Killed or injured pedestrians in different accident types (annual average numbers 2001-2005).

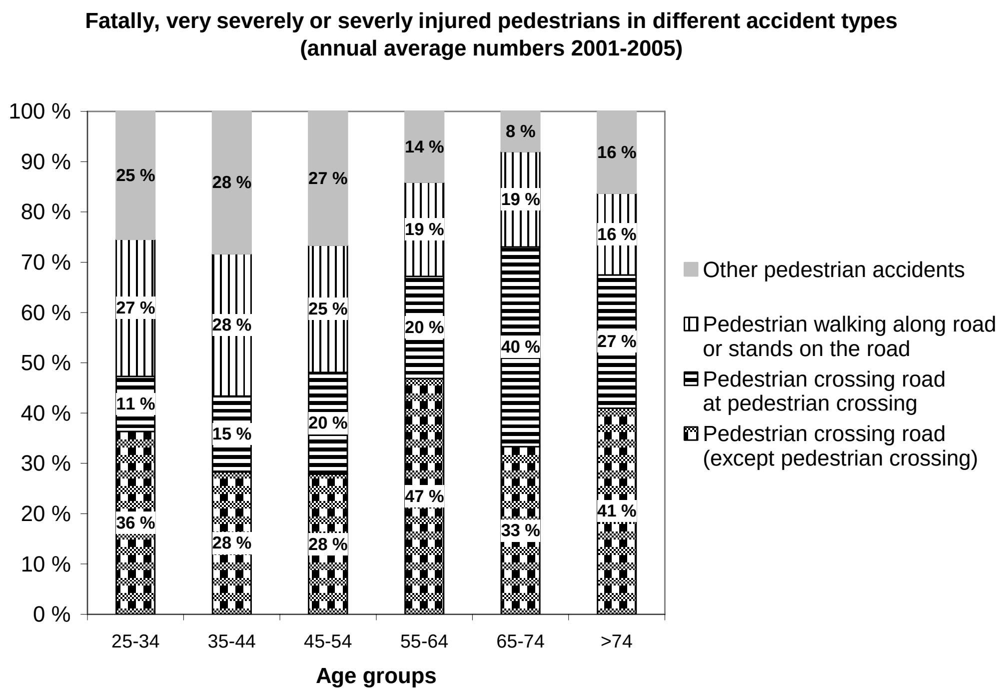

Figure 3.3.2: Fatally, very severely or severely injured pedestrians in different accident types (annual average numbers 2001-2005).

The only exception is the increasing proportion of fatally, very severely or severely injured pedestrians at pedestrian crossings in the two oldest age groups. Most of these injuries occur in intersection accidents. A closer look at the intersection accidents shows that the proportion of fatal, very severe or severe injuries that involve a pedestrian who is hit by a turning vehicle increases from 3% in the age groups 25-64 years to 5% in the age groups 65 years and above. There does not seem to be a (continuous) increase of the proportion of fatalities or injuries in accidents where a pedestrian is crossing a road, when pedestrian crossings are not taken into account.

Most other studies of accident risk in older pedestrians have found that older pedestrians are overrepresented in intersection accidents and in accidents involving a pedestrian crossing a road, especially at pedestrian crossings.

The proportions of fatally, very severely or severely injured pedestrians in different age groups in urban and non-urban areas are shown in Figure 3.3.3. The proportion of fatally, very severely or severely injured pedestrians is on average larger in non-urban areas (19%) than in urban areas (14%). The difference of injury severity do not systematically change in older age groups.

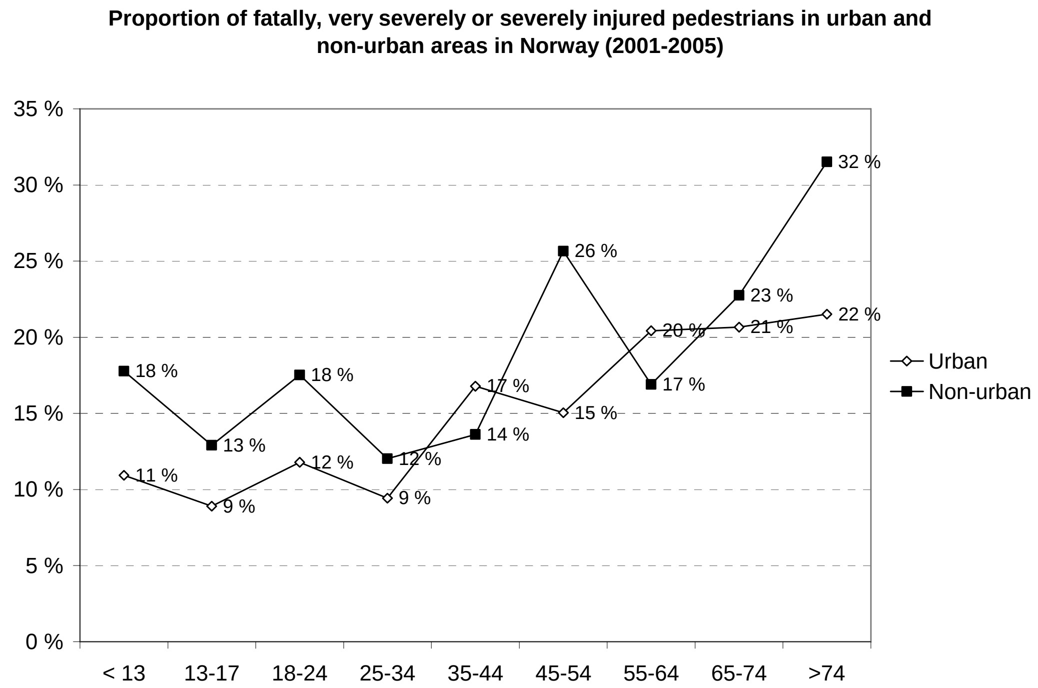

Figure 3.3.3: Proportions of killed or injured pedestrians in urban areas.

3.3.2 Light conditions

The proportions of killed or injured pedestrians in different light conditions are shown in Figure 3.3.4 and 3.3.5. The proportion of fatalities and injuries in the dark is decreasing with increasing age. This may reflect exposure to a larger degree than risk.

Among the fatalities and injuries in the dark, road lighting is more often absent among the fatalities, very severe or severe injuries than among all fatalities and injuries, indicating that accidents in the dark are more severe when there is no road lighting. Among the fatalities, very severe or severe injuries in the dark, the proportion of absence of road lighting is lower in the age groups 55 years and above (14% - 23%) than in the age groups below 55 years (28% - 42%). This may be due to a number of factors, including exposure (older people walking less in the dark when there is no lighting) and behaviour (e.g. more visible clothes among younger adults).

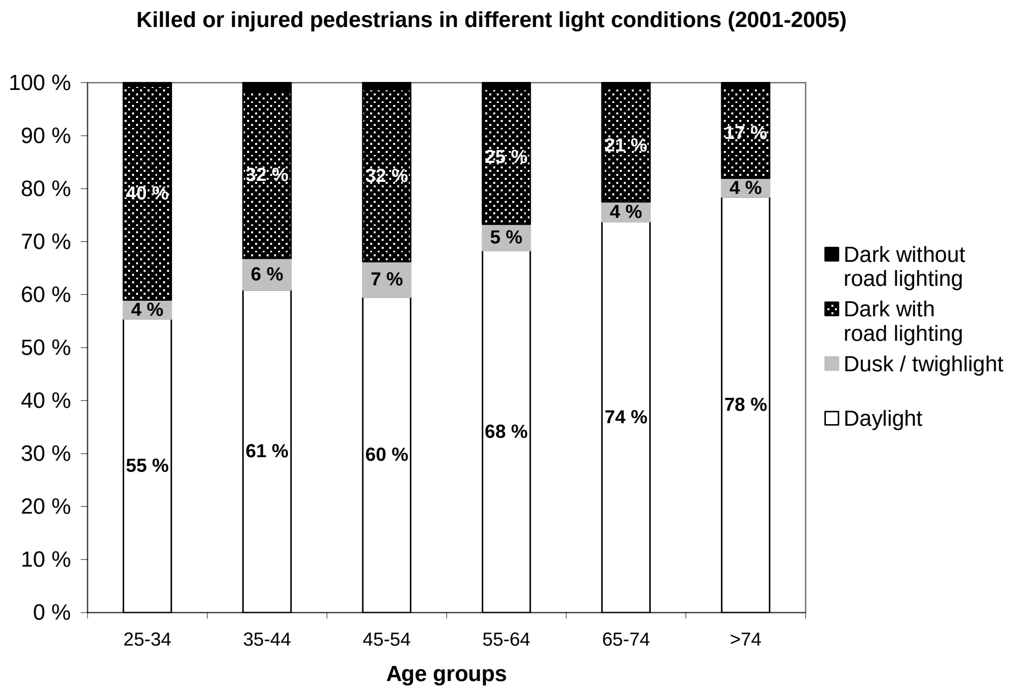

Figure 3.3.4: Killed or injured pedestrians in different light conditions (annual average numbers 2001-2005).

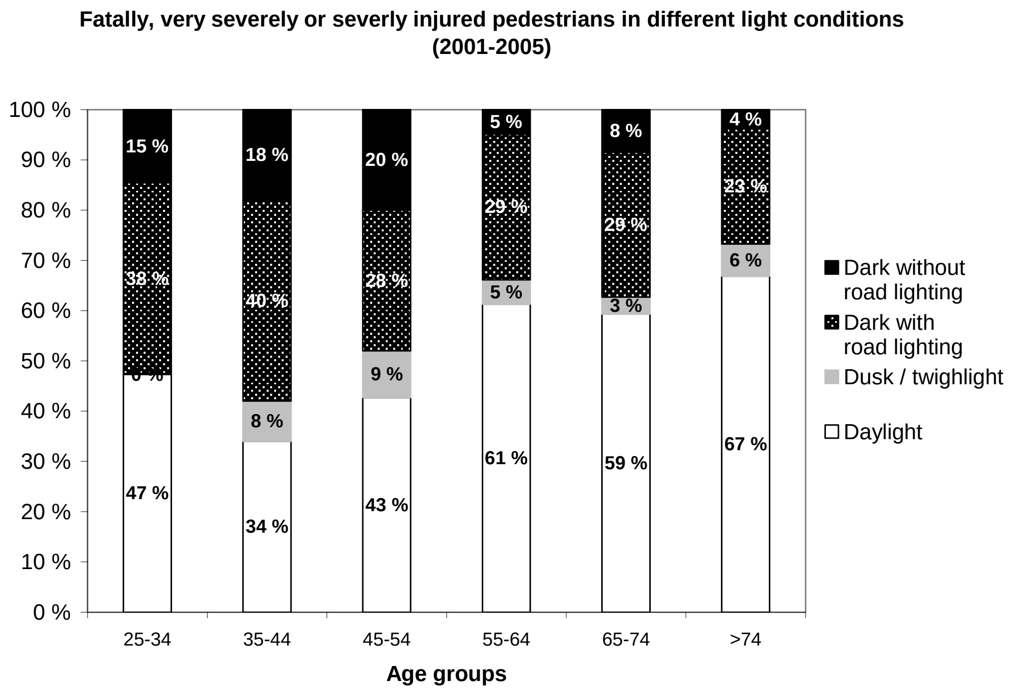

Figure 3.3.5: Fatally, very severely or severely injured pedestrians in different light conditions (annual average numbers 2001-2005).

3.3.3 Road conditions

The proportions of killed or injured pedestrians according to different road conditions are shown in Figure 3.3.6 and 3.3.7. Slippery road conditions include snow, ice and other factors. The proportions of all fatalities and injuries during slippery or wet road conditions is relatively constant in all age groups. This may (theoretically) be due to equal exposure and equal risk (possible), lower exposure and higher risk (likely) or higher exposure and lower risk (unlikely). However, no exposure information is available for different age groups according to different road conditions.

The proportion of fatal, very severe or severe injuries is only slightly larger in the age groups 55 and above than in the younger age groups. Compared to the result for all fatalities and injuries, this may indicate higher risk under slippery road conditions at older ages.

These results do not include falling accidents. Collisions between pedestrians and other road users may however also involve falling or sliding.

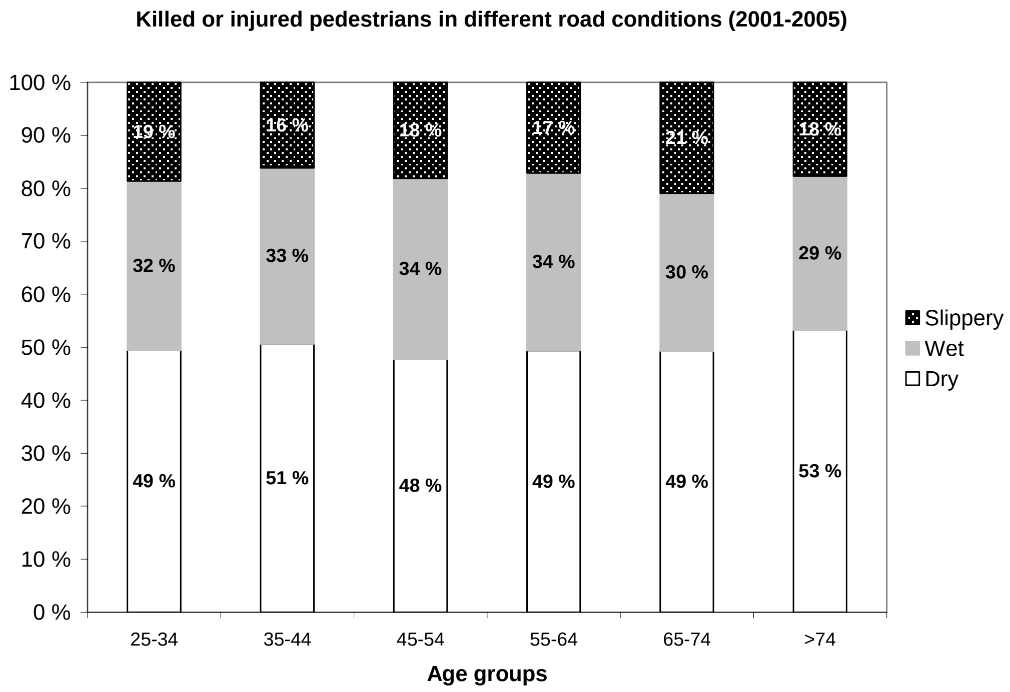

Figure 3.3.6: Killed or injured pedestrians under different road conditions (annual average numbers 2001-2005).

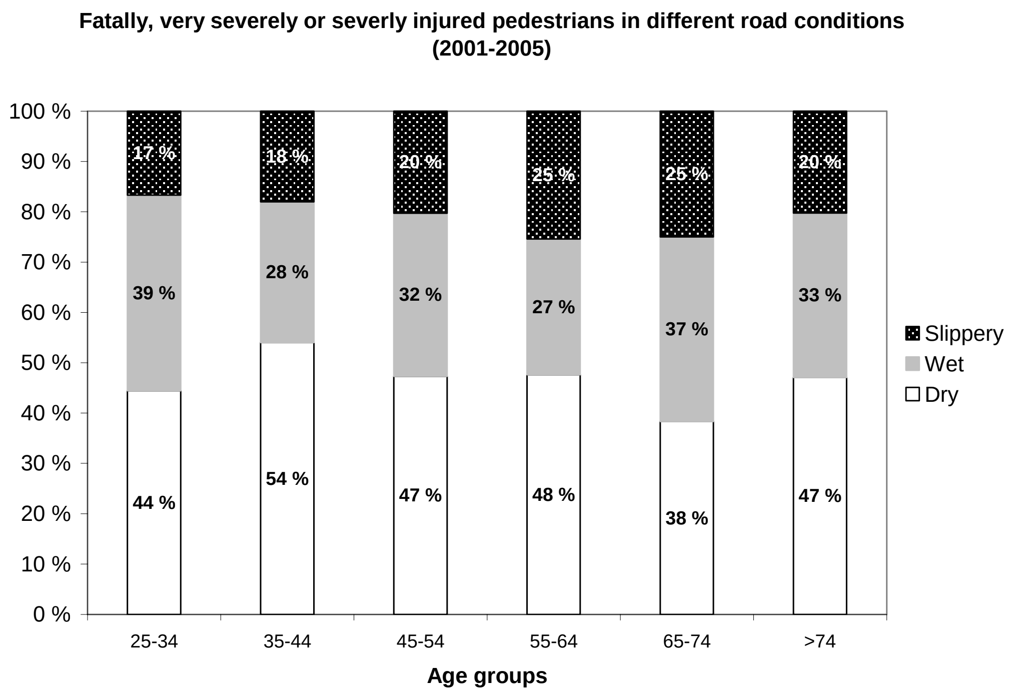

Figure 3.3.7: Fatally, very severely or severely injured pedestrians under different road conditions (annual average numbers 2001-2005).

3.3.4 Visibility conditions

The proportions of killed or injured pedestrians by visibility conditions are shown in Figure 3.3.8 and 3.3.9. The proportion of fatalities and injuries in different visibility conditions does not seem to be systematically changing with increasing age.

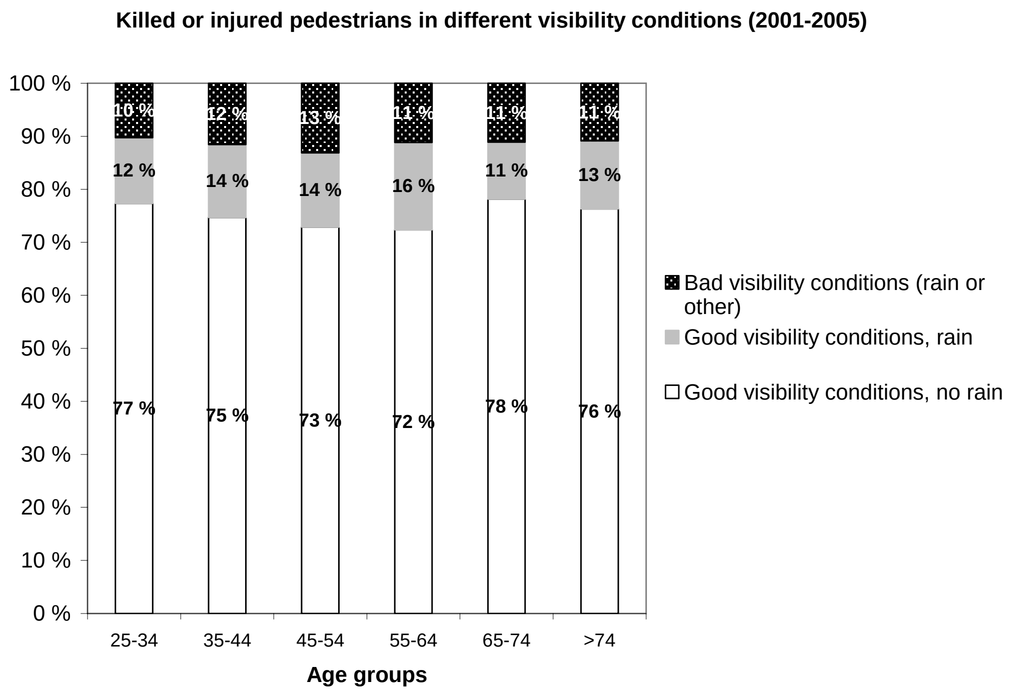

Figure 3.3.8: Killed or injured pedestrians under different visibility conditions (annual average numbers 2001-2005).

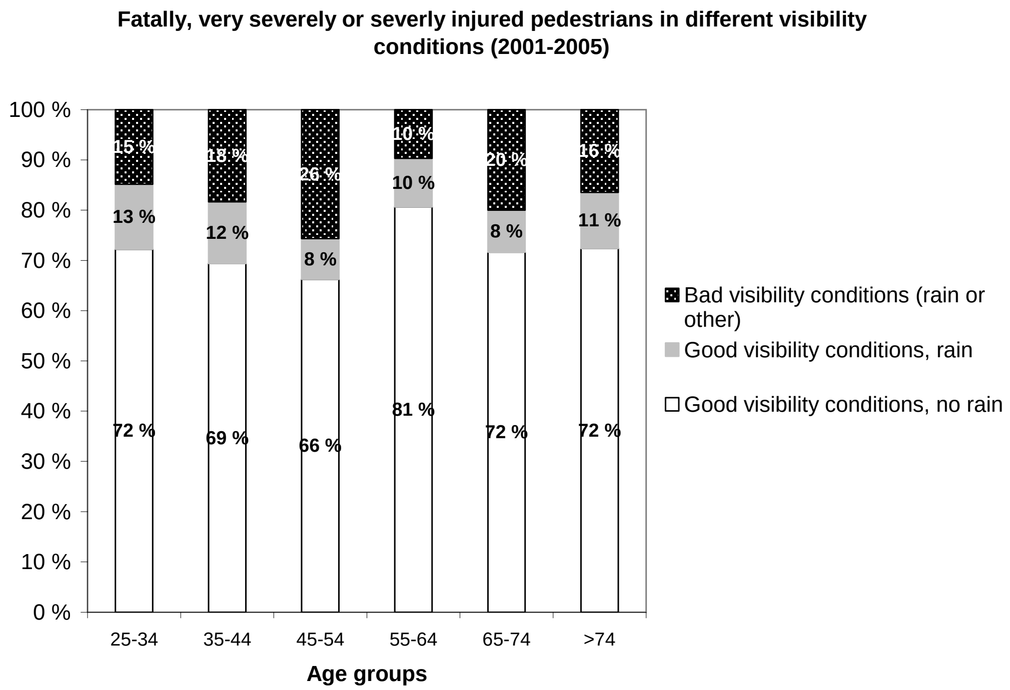

Figure 3.3.9: Fatally, very severely or severely injured pedestrians under different visibility conditions (annual average numbers 2001-2005).

3.3.5 Falling accidents

Falling accidents are not included in road accident statistics. Numbers of deaths related to falls can be obtained from SSB. There is a large number of deaths related to falls in the older age groups. A proportion of these may have occurred in road traffic, but no information is available on whether falls happened in road traffic or in other environments. Only very few fatal falling accidents are related to ice or snow. Among “other falls, same level” there are probably also a number of falls related to road traffic, but the proportion is not known.

The same problem as in Norway is encountered in other countries as regards statistics on pedestrian road accidents that do not involve a (motor) vehicle. In addition to accidents not involving motor vehicles also collisions on non-public roads (e.g. driveways, car parks, footpaths) are excluded from most official accident statistics (Oxley et al., 2004).

Table 3.3.1: Numbers of deaths related to falls, 2004. Source: SSB.

	Age groups					
	25-34	35-44	45-54	55-64	65-74	75 +
All falling accidents	5	9	16	30	56	660
Ice or snow	0	0	0	0	1	2
Sliding or stumbling	0	0	0	0	0	3
Ski, skates, roller skates, skateboard	0	0	0	1	0	0
Other falls, same level	0	2	3	1	4	44
Unspecified, others	5	7	13	28	51	611

No information is available on falling accidents that are not fatal. Non-fatal falling accidents can have severe consequences for older people, especially hip fractures. In Norway there are ca. 9,000 hip fractures each year. Older people are far more likely to suffer hip fractures in falling accidents than young people. Hip fractures with older people are often associated with extensive medical treatments, much pain and a long lasting loss of quality of life (Erke & Elvik, 2007).

4 Risk factors and safety measures for older pedestrians

In this chapter risk factors and safety measures are summarized that are relevant for accidents and injuries among older pedestrians.

4.1 Infrastructure and vehicles

4.1.1 Accident locations

Several studies (Dunbar et al., 2004; Ward et al., 2004) have found that accidents with older pedestrians mostly occur on roads in urban areas which are close to the home of the older pedestrians and where the pedestrians are familiar. In Norway however, accident statistics show that less than half of all fatalities and injuries among pedestrians occur in urban areas, and that there are no differences in accident severity between urban and non-urban areas (see Section 3.3.1).

Other accident types in which older pedestrians are overrepresented are collisions between a pedestrian and a reversing car (Dunbar et al., 2004). Most of these accidents happen on other than public roads (e.g. driveways, car parks) and are therefore not included in official accident statistics.

Accidents with older pedestrians are also likely to occur at locations which are not meant to be used by pedestrians but which are shortcuts for routes which pedestrians experience as unnecessary detours (e.g. pedestrian bridges, tunnels, footpaths around roundabouts, long distances between signalized crossings). Older pedestrians with walking difficulties prefer safe crossing facilities but are easily tempted to use less safe shortcuts (Dunbar et al., 2004).

4.1.2 Crossing facilities and intersection design

A number of studies have found that older people (and children) have higher risk of accidents and injuries at intersections and while crossing roads than other age groups. The accident rates are highest at (unsignalized) pedestrian crossings and on wide streets (Wilton & Davey, 2007; Oxley et al., 2004; Rytz, 2005; Zegeer et al., 2005). According to Koepsell et al. (2002) older pedestrians have a 2.1 times higher risk while crossing marked crosswalks than other pedestrians (after controlling for pedestrian and motor vehicle volumes and site characteristics). The risk among older pedestrians is also higher at crossings on roads with four or more lanes (Zegeer et al. 2005). Older pedestrians are more often than younger pedestrians hit by turning vehicles. Accident risk on different types of roads has been investigated by Ward et al. (1994). When controlling for the total number of crossings, accident risk increases with increasing age on all types of roads. The largest increase was found on primary and district distributor roads, followed by local distributors. On residential roads the smallest increase was found. These results correspond to the preferences of older pedestrians. They prefer crossing roads at signalized intersections and would prefer longer crossing times.

Whether or not intersection accidents are more or less severe than other accidents is not quite clear. Hauer (1988) found injuries at intersections to be less severe than other injuries. In Norwegian accident statistics no such difference is recognizable (see above, Section 3.3.1).

There are many possible reasons for increased accident risk at pedestrian crossings. One reason may be a false sense of security. The longer time it takes older people to cross may also be among the contributing factors. According to the literature surveys by Dunbar et al. (2004), Oxley et al. (2004) and Sagberg & Glad (1999) the behaviour of older pedestrians differs in several ways from the behaviour of younger pedestrians. Older pedestrians

- are less likely to use formal crossing facilities (signalized or marked crosswalks) when this requires more walking,
- are more likely than younger pedestrians to comply to rules, i.e. walk more seldom at red light (research on older drivers indicates the contrary, see above section 2.2.3),
- are more cautious, wait longer and observe traffic, keep further away from kerbs, avoid walking in the dark or bad weather,
- follow often younger pedestrians,
- make more often misjudgements about approaching vehicle speeds and gaps, are more likely to overlook vehicles and to misjudge driver behaviour,
- need more time for crossing roads because they are walking more slowly, and need therefore larger gaps,
- are often very carefully observing traffic in the first half of the road they are crossing, but fail to observe traffic in the second part of the road,
- are more afraid of collisions with vehicles and of falling, and find it more difficult to gather information in complex traffic situations.

These results show that older pedestrians are (trying to) compensate for perceptual and physical limitations, but often are not succeeding, especially in complex traffic environments.

Selecting a gap is often a major problem for older pedestrians, because it imposes high attentional demands and requires intact cognitive-motor skills. Older pedestrians experience problems especially in high-speed environments, on roads with more than two lanes and when approaching traffic from more than one direction has to be observed because of the higher attention demands in such situations (Oxley et al., 2004). On roads in which traffic has to be observed only from one direction, older and younger pedestrians are more similar as regards gap selection. In the study of Lobjois & Cavallo (2007) similar safety margins and proportions of unsafe crossing decisions on a single-lane one way road have been found which indicates that older pedestrians are able to compensate for the required longer crossing times. Oxley et al. (2005), who have investigated crossing behaviour not only on two lane roads, found more dangerous gap section decisions among older pedestrians. The most important decision criterion in this study was vehicle distance rather than time of arrival. This was found in all age groups, not only among older people.

A Norwegian in-depth study (Ytrehus & Sakshaug, 2006) of pedestrian accidents at pedestrian crossings found mistakes made by the pedestrians to have contributed to 50% of all accidents. The most frequent mistakes were

- expecting that an approaching vehicle will stop (25%),
- non-use of reflective materials (17%)
- crossing without stopping and looking (9%),
- sudden and unexpected changes of walking direction (7%),
- falling was involved in 1% of all accidents.

In total, there were more mistakes made by pedestrians above 70 years, both among fatally or severely injured and among slightly injured. The number of pedestrians in the study was however too small to investigate difference of types of mistakes between age groups.

At signalized pedestrian crossings, there is according to studies from the US often not enough time for older people to cross (Oxley et al., 2004; Wilton & Davey, 1997).

Driver behaviour may affect the increased risk of older pedestrians at unsignalized pedestrian crossings. Several studies have found that drivers in general have low willingness to give way to pedestrians and that drivers involved in collisions with older pedestrians have lower compliance and worse driving records than drivers involved in collisions with younger pedestrians (Oxley et al., 2004).

The design of signalized pedestrian crossing can be adapted to the demands of older pedestrians in several ways. Countdown signals showing the number of seconds until red are perceived as improving safety, although no safety effects have been found in evaluation studies.

Another device is puffin (“Pedestrian User Friendly Intelligent”) crossings, which use microwave device for the detection of pedestrians who are waiting to cross and of pedestrians who are crossing (Sagberg & Glad, 1999). Based on these devices, the duration of green light is automatically adapted to waiting and crossing pedestrians. There is no blinking green light between the green and the red light. Slower pedestrians have sufficient time to cross at green light with this device, and at the same time delays for motor vehicles are reduced to a minimum.

A general increase in pedestrian green phases is not always adequate because also delays for motor vehicles must be taken into account. Additionally, delays which are perceived as unjustified may reduce compliance and increase red-light running. Footbridges or tunnels may be adequate but should be designed so as to avoid both detours and difficult or dangerous stairs or grades.

Unsignalized pedestrian crossings can be made easier and safer to cross for older pedestrians by installing traffic islands. This reduces the attention demands because approaching traffic has to be observed on fewer lanes and from only one direction (Sagberg & Glad, 1999). The distance that has to be crossed can be shortened by installing “noses”, i.e. widening footpaths and narrowing lanes (Rytz, 2005). Lowered kerbs can also make it easier for older pedestrians to cross. In a Swedish study (Leden et al., 2006) several measures have been found that made crosswalks safer, especially for older pedestrians and children: improved visibility conditions, marking crosswalks, and installing speed humps ca. 2 car lengths in front of the crosswalk. The introduction of a new law according to which drivers always have to yield at pedestrian crossings has lead to an increase in accident risk for pedestrians at pedestrian crossing. A possible explanation is an increased false sense of security.

4.1.3 Speed reductions

In collisions with motor vehicles pedestrians are more likely to be killed at higher speeds compared to lower speeds. The risk of fatal injuries increases for an average pedestrian slowly up to ca. 30 km/h and increases steeply at speeds above ca. 30 km/h. Because of the lower tolerance for injuries, older pedestrians are more likely to be killed in collisions with motor vehicles than younger pedestrians at all speeds. The steep increase of the risk of fatal injuries starts at lower speeds for older than for younger pedestrians (Oxley et al., 2004).

Speed reducing measures generally reduce the risk of fatal and severe injuries, but no studies have been found that have investigated the effects on older pedestrians. Because of the more severe injuries older pedestrians sustain from collisions with motor vehicles, speed reduction measures are likely to be more effective for improving the safety of older pedestrians than for improving the safety of younger pedestrians (Dunbar et al., 2004). Speed reducing measures include speed limits, enforcement and infrastructure measures. Area wide interventions in areas with large proportions of older population are likely to be most successful.

Speeds are higher in rural areas than in urban areas. However, also in urban areas, where most walking takes place, speed is often above the speed where pedestrians are likely to survive collisions with motor vehicles without severe injuries.

4.1.4 Road maintenance

Road maintenance refers to the condition of the road surface and to winter maintenance. In a British study, 55% of all older pedestrians experienced problems with cracked pavements, 31% with snow and wet leaves (Dunbar et al., 2004).

A Swedish study (Oberg, 1998) found that the risk of sustaining injuries in falls is much greater among older pedestrians than among younger pedestrians. Injury risk among pedestrians in urban areas on roads that are covered by ice or snow in winter was found to be six to eight times higher than injury risk in summer. In ca. 80% of all pedestrian single accidents (i.e. falling accidents) the condition of the road surface has been a contributing factor. Another Swedish study found that slipping on ice or snow causes 350 injuries per 100,000 inhabitants in Umeå (Björnstig et al, 1997). The most part of these injuries occurred while walking along streets. Medical costs are estimated by Björnstig et al. to be almost equally high as the medical costs for all other traffic injuries that occurred during the same time period.

Improvement of winter maintenance does not always reduce the number of falling accidents. Possible explanations are more walking and less caution on roads that are salted or cleared from snow. On roads with snow or ice, there is less pedestrian traffic, pedestrians are walking more cautiously or use heel spikes. Winter maintenance can also make roads more slippery instead of less slippery. In total, winter maintenance is therefore not always a safety measure but improves mobility and the (subjective) feeling of safety while walking (Elvik, 2000).

4.1.5 Traffic environment and infrastructure design

The traffic environment is often experienced as a safety problem and as a barrier to mobility by older people. The general design of road infrastructure can contribute to making it safer (and more pleasant) to be a pedestrian for older people (Dunbar et al., 2004; Oxley et al., 2004; Transport Research Center Brno, 2003):

- adequate pedestrian facilities, that are safe both objectively and subjectively, pleasant and that do not tempt to (less safe) short cuts,
- separation of pedestrians from motorized traffic, especially high-speed traffic, without creating detours or other difficulties for older pedestrians such as stairs or grades,
- road maintenance and winter maintenance, i.e. repairing asphalt and avoiding slippery roads, and removal of parked vehicles from footpaths
- reduce complexity and attention demands, e.g. by avoiding situations where approaching traffic from different directions has to be observed, by installing easily understandable signs and signals, and by making crossing facilities consistent
- installation of rest areas (benches) in areas with many older pedestrians,
- designing the traffic environment as a whole according to the principle of the "weakest link" (e.g. the installation of road lighting along a whole route and not only in parts, which would make the whole route equally unattractive as without lighting)

4.1.6 Road lighting

Road lighting increases visibility at night and has been found to reduce pedestrian accidents in several studies (Vejdirektoratet, 1998). Road lighting also reduces subjective feelings of insecurity and reduces crimes like assault and robbery. It can therefore make walking for older pedestrians more attractive. Older pedestrians are feeling more uncomfortable on unlit roads and unlit roads pose larger problems when they have visual impairments or are afraid of stumbling or sliding. Older pedestrians are also more than younger pedestrians afraid of becoming victim for assault or robbery (Wilton & Davey, 2007).

4.1.7 Vehicle design

Collisions between pedestrians and motor vehicles have usually severe consequences, especially at higher speed. Older pedestrians are generally more vulnerable to injuries from impacts. Causes of death in pedestrian vehicle collisions also differ between younger and pedestrians. A number of studies (summarized by Oxley et al., 2004) have found

- a larger proportion of fatal injuries among older than among younger pedestrians, 2% of injuries were fatal in the age group 20 to 50 years and 9% were fatal in the age group 80 years and older, and older pedestrians are overrepresented among killed pedestrians,
- higher fracture rates among older pedestrians (over 65 years) than among younger pedestrians, and higher fracture rates among older women than among older men,
- the most frequent severe injuries are head and lower extremity injuries, both among older and younger pedestrians,
- chest injuries, especially rib fractures, and extremity injuries lead more often to death among older than among younger pedestrians and may be a more important cause of death than head injuries (head injuries are a more important cause of death than chest injuries among younger pedestrians),
- older pedestrians have larger risk of dying from hip fractures than younger pedestrians.

Improved vehicle design and speed reductions in environments which are used by motorized and non-motorized traffic are therefore likely to have larger positive effects on older pedestrians than on younger pedestrians. According to Oxley et al. (2004) however, almost nothing is known about specific effects of vehicle design on older pedestrians.

4.2 Measures addressing road users

Other road users have often negative attitudes towards older pedestrians and show less respect for them (Oxley et al., 2004). A study from Switzerland (Rytz, 2005) has found that in 72% of all collisions between a car and an older pedestrian the fault was exclusively with the car driver. Observational studies which have been reviewed by Rytz (2005) have shown that car drivers are less frequently giving right of way to older pedestrians than to other adult pedestrians and especially less than to children.

Less respect of other road users is a special problem for older pedestrians because they more often than younger pedestrians get in situations where they are dependent on other road users. Such situations occur when older pedestrians do not (sufficiently) observe approaching traffic in the other half of a road they are crossing, when they are crossing in front of turning vehicles, and generally when they are crossing more slowly.

4.2.1 Enforcement

Measures that address drivers of motor vehicles rather than older pedestrians may be effective in reducing accident risk of older pedestrians, although evaluations have only seldom been carried out (Dunbar et al., 2004). Enforcement measures that may improve the safety of older pedestrians are speed enforcement in areas where many older pedestrians are walking, and enforcement of parking regulations around pedestrian crossings and along footpaths (Zegeer et al., 2005).

4.2.2 Education and training

Although some studies indicate that the behaviour of older pedestrians might be improved by educative measures, the effectiveness of education programs and of information campaigns in improving behaviour or accident risk is often questioned (Dunbar et al., 2004; Oxley et al., 2004). Reasons are for example reluctance to learn new behaviour and to change habits.

Dunbar et al. (2004) have provided a list of advices that should be given to older pedestrians. The advices focus on the following (risk) factors:

- general information on prevalence and relevance of functional declines and possibilities for compensation
- feedback seeking
- vision and hearing checks and use of vision and hearing aids
- effects of walking on well-being and health
- traffic behaviour: avoidance of complex situations and high-speed roads, criteria for gap-selection, choice of crossing facilities, visual search, respecting right of way
- seeking additional support
- information on effects of alcohol, medication and diseases,
- conspicuousness, use of conspicuous clothing and retroreflective patches

Training of attention or physical fitness may reduce accident risk and vulnerability. An aspect of attention that is relevant for accident risk and that can be improved by training, is the useful field of view (see above Section 2.2.4). Training of physical fitness can improve balance and walking speed and thereby reduce accident risk, especially the risk of falling accidents (see above Section 2.2.5). If physical fitness is trained by walking, the increased exposure may increase the total number of accidents, but the risk per walked kilometre would decrease because more skills would be acquired (Rytz, 2005). However, no studies on the effects of training programs for attention, physical fitness or of increased walking on accident risk have been found.

Studies on falls prevention programmes have found reduced risk of falling accidents, increased mobility and improved health (Beard et al., 2001; Hirsch et al., 2001; Powell et al., 2000), but these studies have not specifically focused on falling accidents in the road environment. These programmes include physical activity, strength training, and a number of different psychological aspects.

According to Ulleberg (2006) a training programme for older drivers in Norway which aims at improving knowledge about traffic rules and to exchange experiences in road traffic, has had positive effects on accident involvement of the participants. Participation in these courses is a voluntary offer to all drivers above 65 years. It consists of discussion rounds, were the topics can be chosen by the participants.

4.2.3 Other measures

One possibility to increase the probability to make other road users more aware of older pedestrians is the use of clothes in bright colours and the use of reflective devices. This will increase the visibility of pedestrians, but may not change attitudes of other road users.

4.2.4 Measures addressing functional impairments

A number of measures address specific functional impairments and may reduce accident risk of individuals within high risk groups. As the research that has been summarized in the preceding sections has shown however, there are not many functional impairments that can explain increased accident risk among older pedestrians. No or only weak relationships have been found between vision or hearing and accident risk, most likely because the impairments are compensated or because exposure is reduced. Spectacles or hearing aids may therefore increase mobility more than directly reduce accident risk.

Functional impairments that are more directly related to accident or injury risk include more complex cognitive functions. Cognitive functions, such as attention and processing speed, may be improved by specific training, and are also less likely to decrease at high levels of physical activity where such functions are required. These functions may also be improved directly by training.

4.2.5 Post accident care and rehabilitation

Injuries have often more severe and more long-lasting consequences among older than among younger pedestrians. Older people spend for example more time in hospital, are more likely not to recover fully, and more likely to experience subsequent accidents. This is well documented for falling accidents. Older people who have had a falling accident are much more likely to fall (again) than older people without previous falling accident. Little is known about psychological consequences of accidents and injuries among older pedestrians. They are likely to be significant because hip fractures cause much pain and they may reduce mobility and thereby independence (Dunbar et al., 2004). Rehabilitation measures are therefore important for older pedestrians after accidents in order to regain life-quality. An evaluation of rehabilitation after hip fractures has shown that workout and psychological interventions reduce the probability of future hospitalization and improve quality of life considerably (Hirsch et al., 2001).

After an accident many injuries require immediate treatment and consequences of injuries can become more serious if treatment is delayed. Devices that assist in calling for help and locating the accident site can therefore contribute to reducing injury severity and preventing fatalities (Clark & Cushing, 2002). Manually operated devices are also a possibility for older people to call for aid, especially in the case of falling accidents where no other people may be present. The most simple devices are mobile phones, but devices which additionally allow the precise location are also available.

4.3 Falling accidents

Older people are more likely than younger adults to sustain injuries in fall accidents (Oxley et al., 2004). Falling accidents among pedestrians are more common than collisions with vehicles, especially among older women (Dunbar et al., 2004). The risk of sustaining injuries in falling accidents in road traffic has been estimated in a number of studies (Dunbar et al., 2004; Oxley et al., 2004). The estimates range from four to ten times as many injuries in falling accidents than injuries in motor vehicle accidents.

Falling accidents can be caused by external or internal factors. External contributing factors are road conditions such as slipperiness, unevenness or obstacles. Internal contributing factors are general problems older people have with walking, balance, and stability and visual impairments. These problems may directly lead to falls, and they make older pedestrians more vulnerable to sliding or stumbling. Stability problems increase the amount of attention that has to be spent on walking and thereby decreases the amount of “available” attention for other tasks, such as monitoring the traffic environment (Dunbar et al., 2004).

Among falling accidents, slipping usually leads to more severe injuries than stumbling (Dunbar et al., 2004). Fall accidents are usually less serious than pedestrian-vehicle collisions, they involve less fractures and less severe head and chest injuries (Oxley et al., 2004). Both falling accidents and fractures sustained in falling accidents are most frequent among older women (Dunbar et al., 2004).

Falling accidents and injuries sustained in falling accidents are affected by a number of factors, each of which may be addressed by different measures:

- Physical exercise can improve balance and walking speed (Dunbar et al., 2004). Since walking also is a physical exercise, measures that increase the amount of walking (without imposing extra risks on older pedestrians) should be expected not only to improve mobility and health but also to reduce the risk of falling accidents.
- Infrastructure measures that reduce attention demands can indirectly reduce the risk of falling accidents. Infrastructure measures like road maintenance and winter maintenance reduce the risk of sliding or stumbling and improve mobility.
- Removal of parked vehicles from footpaths improves mobility and reduces sight obstacles and sources of frustration for older pedestrians.
- Separation of walking and cycling reduced potential conflicts between pedestrians and cyclists.
- Appropriate footwear and anti-sliding devices for shoes (spikes) improve balance and reduce the risk of sliding.
- Protective equipment (hip protectors) is effective in reducing injury severity, but may suffer from a lack of acceptance.

A programme against falling accidents that address several risk factors is ‘Stay on your feet’ (Beard et al., 2006). This programme has been conducted in Australia. It is composed of the following elements: Establishment of “Safety Walking Groups” which represent pedestrians interests and engage in several activities related to the programme, checks of infrastructure facilities, public buildings, homes of older people, offers of physical training and checks of medication and spectacles. Evaluations have shown that the program has reduced hospitalization due to falling accidents by 20%. This program focuses however not only on falling accidents on roads, but on all falling accidents.

Several other community based interventions have been summarized by Dunbar et al. (2004), which include systematic appraisal of injury risks for older pedestrians or for older people in general, the education of "peer educators", information and education programmes. Actual effects on accidents and injuries have however not been found.

4.4 Strategies for promoting cycling and walking

In European countries there are a number of activities in order to promote walking and cycling and to increase the proportion of short trips that is walked or cycled instead of driven by car. However, many of these strategies do not explicitly address safety aspects and most do not specifically address older pedestrians (Oxley et al., 2004).

5 Mobility of older pedestrians

Mobility refers to locomotion from one point in space to another. It is also a potential, i.e. the existence of the possibility to move to another location. It is an option and not moving is therefore not the same as not being mobile. This Chapter addresses general aspects of the mobility of older people and social and health effects of mobility and injury risk.

5.1 Modes of travel

Many studies have found a generally decreasing travel activity at increasing age, which is to a large part related to less trips to work, education or other activities which require travelling. Travel by car is reduced most, partly because of increasing physical impairments, although many old people continue driving in spite of impairments which make driving quite unsafe (as can be seen in accident statistics). Especially on short trips, car trips are often replaced by walking trips, and walking trips to public transport may also increase.

Travel by car is, all the same, the most preferred and the safest mode of travel for older people according to the literature survey by Oxley at al. (2004). According to studies made by Transport Research Center Brno (2003) it is a "mere myth that elderly people would be happy to voluntarily give up driving their own cars if a bus stopped right in front of their homes". Non-availability of a car is one of the most important reasons for walking (often in combination with public transport). Older people who have a car available are therefore more satisfied with their mobility (Oxley et al., 2004).

The total amount of walking also decreases at older ages. This may be partly because of functional impairments which make walking more risky, more laborious, or otherwise unattractive. Some authors even recommend that older people should abandon walking and rather drive a car (or be driven) in order to reduce injury risk while walking.

Pedestrians who gave up driving a car are a special group of pedestrians. Being previous car drivers, this group is likely to have higher demands to mobility. They are also likely to suffer from impairments which made them stop or reduce driving (Dunbar et al., 2004). This combination makes previous drivers a potential high risk group of pedestrians. On the other hand, previous drivers are more familiar with moving in traffic environments and know more about traffic rules and driver behaviour. However, not much is known about older walking ex-drivers. As regards research and measures for improving safety and mobility, this group of pedestrians is not unimportant. The group is likely to be growing in the coming years, it is possibly more exposed to accidents, and likely to suffer more from mobility losses than other older pedestrians.

Despite much focus on cars, walking also has a number of advantages and is often chosen voluntarily, as described in the following sections.

5.2 Incentives and obstacles and for walking

Purposes with walking trips are for the most part trips to and from public transport, shopping and recreation (Oxley et al., 2004). In Norway, the most important purposes with walking trips are shopping and recreation (Hydén et al., 1998). Positive effects of walking which may serve as incentives are (as summarized by Dunbar et al., 2004 and Oxley et al., 2004):

- actual and potential travel (making trips and knowing that trips can be made),
- positive effects of physical activity for health and well-being, walking is seen as a healthy, relaxing and pleasant mode of transport,
- involvement in the local community, participation in social activities.

Walking is also associated with a number of problems for older people which may reduce their on-foot mobility (also summarized by Dunbar et al., 2004, Oxley et al., 2004, and Transport Research Center Brno, 2003):

- general problems with walking (see Sections 2.2.5 and 3.1.2),
- general anxiety, fear of complex or unpredictable situations,
- fear of collisions with cars, not being able to cross roads safely (e.g. before signals change), and fear of falling,
- fear of crime and of getting lost,
- the impression of being second-class road users which often arises from the design of road infrastructure and from the behaviour of other road users.

Because of increasing problems with walking, safe walking facilities are likely to be more important for older people as regards their choice of transport mode. However, no studies have been found that have investigated to what degree an adequate infrastructure design actually increases the amount of walking among older people.

5.3 Mobility, health and quality of life

Mobility is central for almost all aspects of daily life: Physical life (providing food, clothes etc.), social activities, health and well-being, financial and official affairs, leisure activities and intrinsically motivated mobility. For older people characteristics of the environment, which are less important for younger people, are becoming more important for their mobility because they may restrict the opportunities with respect to where, when and how much they are able to travel. If on the other hand, the environment is designed in a way to accommodate it to older peoples needs, the functional impairments of older people are getting less important for their mobility (Transport Research Center Brno, 2003).

Mobility has positive effects on health and well-being because of the positive effects of physical activity, such as walking, and because of the numerous functions of mobility. Physical activity increases both physical and mental fitness, and these reduce the risk of cardiovascular diseases, psychological diseases, falling accidents and the severity of injuries in accidents. Quality of life is also positively affected by mobility. The factors that contribute to quality of life are approximately the same as the purposes of mobility: Physical and psychological health, independence, social relations, and accessibility and opportunities in the environment in general (Transport Research Center Brno, 2003).

Among the negative effects of a loss of mobility are reduced health and reduced quality of life. Negative psychological effects can result because of the function of mobility as a "potential". Reduced mobility can contribute to a loss of self-efficacy, which is the feeling to be able to achieve things. Self-efficacy is important for psychological and physical health, and low self-efficacy is related to depression and suicide (Hirsch et al., 2001). Finally, a loss of mobility may lead to a loss of competence and an increase of passivity. In combination with negative health and psychological effects, this is likely to lead to a further reduction of mobility, which in turn reduces health and psychological well-being. The result is a vicious circle of cumulating reductions of mobility and health.

5.4 Improving mobility of older pedestrians

A number of the safety improvements aiming at older pedestrians in Section 4.2 also improved the walking conditions for older pedestrians and thereby their mobility. Based on these results and on lists prepared by PROMISING (2001) measures that improve the mobility of older pedestrians are:

- attractive walking environments,
- complete networks of walking paths with shortest possible routes and availability of alternative routes,
- accessible and useful information on existing road networks and facilities,
- availability of (easily accessible) resting areas,
- avoidance of obstacles, steep gradients, stairs,
- providing and maintaining good road surfaces,
- reduction of vehicle speeds,
- road lighting,
- good visibility conditions,
- adequate crossing facilities with long enough crossing times.

6 Socioeconomic effects of walking and safety among older pedestrians

This Chapter addresses socioeconomic effects that can be expected from measures that reduce injury risk in road traffic among older pedestrians. Socio-economic cost-benefit analyses of road safety measures usually take into account effects on safety, mobility (travel time) and the environment (handbook 140, Statens vegvesen, 2006). In this chapter an overview is given over aspects of safety, mobility and environmental effects that are different between measures for older pedestrians and other types of road safety measures.

6.1 Safety

Safety effects that are included in socio-economic cost-benefit analyses are usually composed of medical and administrative costs, property damage, productivity loss, and reduced welfare. These costs are assumed to be identical for all types of accidents and for all road users in most socio-economic analyses (Killi, Samstad & Hagman, 2006). Some of the components of these costs are however likely to be different for older pedestrians than for other road users that are injured in traffic accidents.

- Medical costs of injuries are often higher for older people than for younger people because of more severe injuries, longer hospitalization and more need for rehabilitation.
- Loss of productivity is on average lower among injured older people because of retirement.
- Property damage is smaller in accidents were pedestrians are involved than in accidents where only motor vehicles are involved. Injured pedestrians do not imply damaged property (besides clothes) and pedestrians inflict much less damage to motor vehicles than motor vehicles. This is probably independent of the age of the pedestrians.
- Travel delays are smaller for pedestrian accidents than for motor vehicle accidents.
- Reduced welfare is usually included in socio-economic analyses as number of lives lost or numbers of injuries of different severity. Injuries among older people lead often to more pain, reduce mobility and quality of life to a larger degree, and have more long-lasting effects than among younger people. Welfare losses due to injury may therefore be expected to be larger among older people.

There are however also methods for weighting injuries and fatalities according to age, which lead to lower economical values of older peoples lives and quality of life. The most common indices are DALYs (Disability Adjusted Life Years) and QALYS (Quality Adjusted Life Years). DALYs are used by the World Health Organization and by the World Bank in order to be able to compare health issues between countries. DALYs consist of the number of life years lost due to death and the number of life years which are lost due to disability. One year of premature death is counted as one DALY and one year of disability is assigned a value between 0 and 1, depending on the severity of the disability and the age of the injured person. The weighting of life years with age is illustrated in Figure 6.1.1. In the United States the QALYs are more widely used, which are closely related to DALYs.

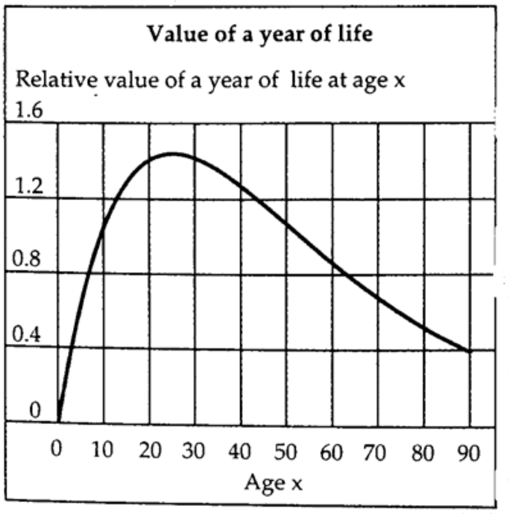

Figure 6.1.1: Relative value of a year of life at different ages (source World Bank).

When DALYs or QALYs are used to assign economic values to avoided fatalities or injuries, older people will be highly disadvantaged. Older peoples lives will have lower economic values than younger peoples lives, and improved quality of life has lower economic values among older people than among younger people. Consequently, when DALYs or QALYs are used in socio-economic analyses, it is far less likely that measures for older pedestrians will be profitable than when fatalities and injuries are assigned equal weights, independent of age.

Safety related effects that are not included in many socio-economic analyses are feelings of discomfort or insecurity, which may be reduced by safety measures (Sælensminde, 2004). Measures for older pedestrians may improve these aspects as well as safety, and thereby increase mobility and quality of life. Improving comfort and a feeling of security may be valued more highly among older pedestrians than among younger pedestrians, and may vary with different travel purposes (recreational vs. non-recreational walking, e.g. to the bus stop).

6.2 Travel times

Travel times in socio-economic analyses are valued per hour of travel, and different values are assigned for different means of transport. Values for pedestrians' travel times are about the same as the corresponding values for travel by other means of transport when the trips are for private purposes (68 NOK per hour). No differences between different travel purposes are assumed for pedestrians as for cars. Since no difference between private trips, trips to / from work and business trips on foot are assumed, it can also be assumed that the values are independent of age. Older pedestrians make more private trips than younger pedestrians and walk more for recreational purposes. When walking for recreational purposes, travel times may be less important than when walking for other purposes, and increased travel times may even be valued positively (on recreational walks) when they involve walking through attractive environments.

Travel times may be far more important for older pedestrians than for younger pedestrians, when increased travel times are caused by detours which are experiences as unnecessary or uncomfortable. As an example, when crossing a street requires walking up and down stairs and crossing a bridge, this may be valued quite negatively. The increased distance and discomfort is however most likely more relevant than the time in itself.

6.3 Environment

Environmental impacts of safety measures include traffic noise, local and global air pollution. These effects are more important for safety measures addressing motor vehicles. If safety measures for (older) pedestrians contribute to a reduction of motorized travel because older people more often walk instead of using the car, environmental effects would become relevant. As has been seen in the literature review, almost nothing is known about how safety measures may affect the choice of means of transport of older people. Environmental effects will therefore be difficult or impossible to estimate.

6.4 Health effects and mobility

Measures addressing the injury risk among older pedestrians can have positive effects on health and mobility due to mutually reinforcing effects of reduced injury risk (improves mobility and health) and improved mobility and health (reduced accident and injury risk; se above section 5.3). Measures may also reduce the fear of falling and improve the accessibility of all types of activities and facilities.

Health effects of increased physical activity include reduced costs of illness and increased personal well-being. Health effects might be possible to value economically, but they are difficult to evaluate because of their complex nature. Increased personal well-being is currently not included in cost-benefit analyses because the consumer surplus is not known (Erke & Elvik, 2007). As mentioned above, injuries and reduced mobility can have serious and long-lasting effects consequences for older pedestrians.

7 Conclusions

The review of accidents, injuries, risk factors and mobility of older pedestrians has shown that older pedestrians are at higher risk than younger pedestrians and that they in many ways are a disadvantaged group of road users.

- Pedestrians are generally more vulnerable than car occupants. Among pedestrians, older people are still more vulnerable. Consequently, older pedestrians are overrepresented among fatalities and severe injuries in road traffic.
- In addition to being more vulnerable, older pedestrians also have increased accident risk.
- The contributing factors to increased vulnerability and accident risk are complex. Safety measures are most promising when they increase physical activity, e.g. by physical and motivational training, by providing practical aids, and by making pedestrian infrastructure less complex, less demanding and more attractive. Addressing specific functional impairments seems less promising.
- Reduced safety is closely related to reduced mobility of older pedestrians. Both injuries and a subjective feeling of insecurity may reduce mobility. Reduced mobility may further increase accident and injury risk because of reduced physical fitness.

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Visiting and postal address:
Institute of Transport Economics
Gaustadalléen 21
NO 0349 Oslo

Telephone: +47 22 57 38 00
Telefax: +47 22 60 92 00
E-mail: toi@toi.no

www.toi.no

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