

PAPER • OPEN ACCESS

## Risks to Older People in Road Traffic

To cite this article: Marcin Budzynski and Agnieszka Tubis 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **603** 042054

View the [article online](#) for updates and enhancements.

# Risks to Older People in Road Traffic

Marcin Budzynski <sup>1</sup>, Agnieszka Tubis <sup>2</sup>

<sup>1</sup> Gdansk University of Technology, 11/12 Narutowicza St., 80-233 Gdansk, Poland

<sup>2</sup> Wroclaw University of Science and Technology, 27 Wybrzeze Wyspianskiego St., 50-371 Wroclaw, Poland

mbudz@pg.edu.pl

**Abstract.** Demographic forecasts show that by 2050 about 25% of Europe's population will be 65 or older. Ageing society translates into older people using roads. An increasing number of older people are drivers, cyclists and pedestrians representing a potential increase in accident risk due to functional limitations. The article looks at road traffic risks and main trends from the perspective of older road users (drivers, cyclists, pedestrians). With a longer time to react, poor eyesight and hearing, impaired mobility, ill health and medication, older road users are put at risk. A comprehensive and pro-active strategy is needed to deal with these risk factors and meet the safety and mobility needs of older people in the (nearest) future. The strategy should focus on assessing the main trends and identifying the road traffic risks for older road users. It should also aim to implement treatments such as ITS and change how road infrastructure is designed today. The objective of the work is to identify the risks to older people in road traffic and develop recommendations on ways to improve the safety of this age group. A study of the literature helped to identify the risk factors faced by older road users. Statistical analyses were used to define the trends, causes and circumstances of accidents involving this age group in the EU and in Poland compared to the EU. The article identifies risks and classifies them for older drivers, pedestrians and cyclists. Needs for universal road infrastructure design are identified (to ensure full accessibility for all age groups, including older people and people with disabilities) and ITS treatments are formulated. EU data shows that about 44% of all pedestrian fatalities are people aged 65 and older. This highlights the seriousness of the problem. With an increasing share of this age group in society and a lack of road treatments to improve the situation, the statistics may deteriorate even further. In Poland drivers aged 65 and older have caused 10% of all accidents involving 14% of all fatalities. Pedestrians in this age group have caused 6% of fatality accidents. The article defines and classifies risk factors in three groups: growing exposure to risk, growing accident risk (factors involving the user directly such as behaviour, illness, functional limitations) and growing accident severity (fatality and serious injury accidents).

## 1. Introduction

The majority of European countries see an increasing share of older people within their populations with forecasts suggesting that in 2080 nearly 30% of the entire population will be 65 and older [00]. The reason for this demographic change is that birth rates continue to drop and life expectancy continues to grow. There are more and more older people using traffic both as pedestrians and drivers and their risk of becoming involved in a road accident increases as well. As people age, limitations emerge which make driving a more difficult task (poorer eyesight, poorer cognitive ability, longer reaction time). Older people are also more likely to be involved in a pedestrian accident. These are



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

some of the challenges for transport policy as a result of ageing populations. This calls for pro-active and informed planning to ensure that older people can stay mobile and safe. The aim of the article was to analyze data on accidents involving older people. The analysis concerned the number of accidents, their circumstances and causes. The article proposed solutions for identified problems as well.

## 2. Literature study

In the literature an older person is defined as someone who is 65 or older [1], [2], [3], [4], [5]. The literature distinguishes younger people who are in old age (65-74 years) and older people who are in old age ( $\geq 75$  years). Mobility goes down at about 75 years of age [1], [6], [7]. While this definition may be seen as subjective, 65 is the official retirement age in many European countries. Please note that age classes do not take account of individual differences between older people. Ageing as a process does not necessarily begin at 65 and its progress may differ from person to person. As an example, some 80 year olds may in fact be in better health than some 65 year olds. This leads to significant differences between how older people of the same age move or between their physical and mental capacities [8].

The effects driver age on risk perception have been studied extensively for a number of years. The focus is mainly on two age groups that are most at risk: young drivers (aged up to 24) and older drivers aged 65 and more. This is because the majority of research suggests that the youngest and oldest drivers have much higher fatal and non-fatal crash risks than drivers in the middle-age ranges [9], [10], [11], [12], [13], [14].

This article centres on the second group of drivers. As we know in industrialized countries, there is a rapidly growing group of older drivers who are used to using private cars and also want to continue using them later in life [15]. Older drivers and their road safety-related problems have drawn considerable attention since the 1960s, when studies came out arguing that the elderly represent a risk in traffic [15]. Several studies have also found differences in fatal and nonfatal crash risks among subgroups of older drivers. For example, there is evidence that drivers aged 70–74 exhibit lower crash risk relative to drivers aged 75–79, with the highest risk seen in drivers aged 80 and older [16], [17], [18]. After age 60, with a sharp increase after age 80, driver fragility and over-involvement in crashes is estimated to account for 34–45% of fatal crash risk [19]. The authors suggested that fragility is of “over-riding importance in explaining the increased fatality risk per unit of travel among older drivers”, however excess crash involvement became a clear contributing factor among older drivers at ages 75–79.

Research conducted worldwide shows that there is widespread agreement that normal ageing is generally accompanied by the onset of specific medical conditions [20], [21], [22], resulting in declines in sensory, perceptual, cognitive, psychomotor and physical functioning [20], [23]. The claim that older drivers subsequently have reduced driving skills and by extension, increased crash involvement, is supported by their apparent over-involvement in crashes. Many elderly suffer confusion, inattentiveness and slow perception and decision time. The perception and reaction time represents “swiftness of reaction” and reaction time of elderly people is 30% longer than that of young people from 300 to 700 ms [24]. Decisions are less likely to be taken almost simultaneously and executed in parallel, but rather in sequence. The decline in muscle strength that accompanies aging has long been recognized. Vision and cognitive ability are important for driving, steering, braking and looking sideways. As a consequence of ageing, perceptual ability, cognitive function and muscular strength deteriorate which may affect driving, cycling and walking in a safe manner. Visual acuity/glare recovery and peripheral vision decrease with age, and distance perception is faulty at low luminance. [24]. Hearing impairments related to the ageing process occur in 13% of elderly people (60+). Hearing loss may cause problems in localizing sounds and consequently in ascertaining from which direction a vehicle is approaching [25]. Loss of physical mobility is common for elderly road

users because of a general weakening of the body and stiffness in the joints. Strength declines in the elderly, ranging from 0% to 30% per decade, depending on age group, muscles and walking speed. This effect becomes more pronounced with advancing age beyond 65 years [26]. Brake reaction / movement time increase approximately 2% every five years, starting with age 15 and ending with people aged 75 and older [27].

Many authors, however, stress that the conventional interpretation of older drivers' safety status recognizes that the crash risk curve based on distance driven, exaggerates older drivers' crash risk due to the 'frailty bias'. Older adults' biomechanical tolerances to injury are lower than those of younger persons [28], primarily due to reductions in bone strength and fracture tolerance [29]. Therefore the energy required to produce an injury reduces as a person ages [30] and thus increases the likelihood of serious injuries among older drivers involved in a crash. This results in a larger share of older drivers' crashes being included in casualty databases, thereby contributing to an apparent over-representation in crashes.

Langford and others [31] have studied the effects of average weekly distances covered by older people on the quality of how they drive. Studies were conducted in New Zealand which helped researchers to establish that drivers who travelled low mileages were liable to have more crashes per distance driven than drivers with higher mileages. Older drivers travelling 20 km or less per week had around ten times the per-distance crash rate of drivers travelling 200 km or more per week. The analyses presented in this paper also showed that low mileage drivers were more likely to report a reduction in their driving performance and to report a range of health and medical conditions.

Accidents involving older drivers tend to be serious especially when the situation is complex. This includes heavy traffic with side impact collisions at intersections which frequently appear to be directly caused by the elderly road users who fail to respond to stimuli and/or took longer time to respond. Intersections are a particularly dangerous location for drivers, pedestrians and bicyclists. Studies conducted in the US in the 1990s prove that the risk of a fatal crash for older drivers aged 65–69, compared with the risk for drivers aged 40–49 in the U.S. was 2.26 times higher for multiple-vehicle involvements at intersections and 1.29 times higher in all other situations [32].

Various studies have examined the impact of intersections or driving scenes of varying complexity on drivers' visual scanning, decision-making and performance [33], [34], [35], all of which have some bearing on overall safety. The role of the complexity of intersections leading to increased crash risk is of particular concern among older adults [36]. Older adults tend to exhibit sensory, perceptual, cognitive and motor declines [37], all of which can impact their ability to deal with the complexities of intersections. Crash data corroborates some of these known deficiencies; older drivers have been identified as having a higher frequency of intersection crashes involving vehicles crossing paths prior to the collision, compared with their involvement in all crash types [38]. Moreover, in documenting critical driver errors involved in serious crashes in the NMVCSS, [39] found that over 70% of older drivers' (aged 70 and over) surveillance errors involved attentional failures, such as looking but failing to see vehicles or traffic control devices. In their road safety policies many countries introduce additional preventative measures designed for the elderly. Japan is an example [40]. The country's additional requirements targeting older people are primarily caused by Japan's population characteristics with elderly people aged 65 or greater comprising more than 20% of the entire population. Japan is currently one of the top-ranked aging nations in the world. Japan's elderly population growth rate is markedly higher than that of European countries and the US. As a result, drivers aged 65 and more represent a substantial percentage of not only drivers but also road accident casualties. In a bid to improve road safety a new law requires a license renewal course for the elderly. Presently, if the expiry date on the driver's license extends beyond the holder's 70th birthday, the driver is obligated, under the Road Traffic Law, to enrol in a license renewal course for the elderly.

The course is intended to make the participants aware of changes to their driving behaviour through lectures and advice on safe driving, driving aptitude tests using driving simulators, and assessments of actual driving performance [41]. Furthermore, for participants 75 years old or more, cognitive function tests to detect memory impairment and disorientation have been incorporated as a criterion for driver's license renewal in the revised Road Traffic Law effective June 2009.

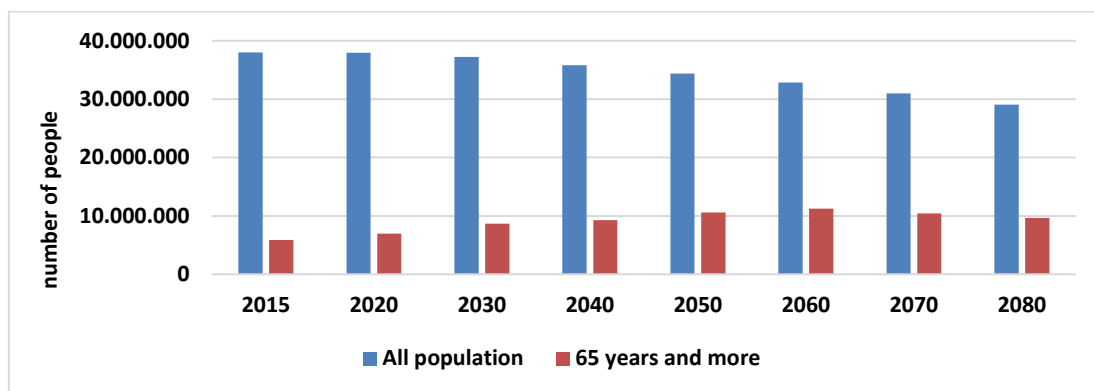
Poland too has been recently engaged in a debate on regular checks for drivers aged 60+. In 2018 the ministry of infrastructure prepared a draft bill on mandatory health checks for older drivers. The European Union is also working on similar legal regulations. In keeping with its road safety policy the EU aims to have mandatory regular health checks for older drivers and make it a requirement for all of the Community's member states. Accident investigations suggest that crashes may be caused by older people when they faint or lose consciousness. This risk is very high for the elderly [42], [43].

Pedestrians aged 65 and older represent another group of road users which is extensively studied. Walking represents a large part of all trips, especially for shorter distances. Yet the road environment is becoming more and more complex [44]. With vehicles dominating the space, high speeds and heavy traffic on many roads used by pedestrians, older people are faced with increasing demands placed on their adaptive skills. This combined with their diminishing capacity to deal with traffic situations puts older road users at a disadvantage when they use road traffic [45]. Pedestrian accidents represent a large portion of road accidents, especially fatality accidents. In Europe pedestrians as fatalities represent more than 21% of all road deaths. International data shows that pedestrian deaths are a major road safety problem, especially in developing countries with a share nearing 70% of all fatality road accidents [46], [47], [48], [49]. A significant part of these accidents involves older people who are susceptible to risks as a result of becoming less agile in road traffic. In EU countries the average number of older people who are victims of fatal pedestrian accidents in 2017 was 47%. Please note the strong differentiation between the countries, ranging from about 60% of all fatalities in this age category in Greece, Italy and Portugal to 33% in Estonia [49].

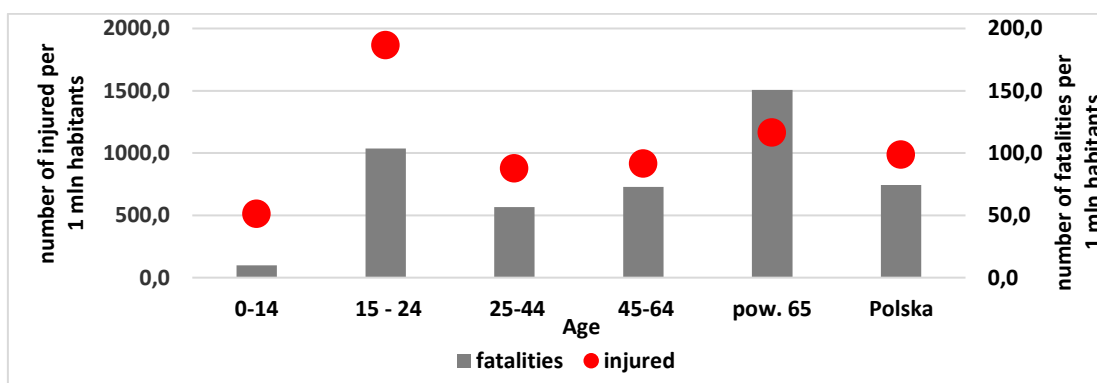
Older people who are involved in an accident are at a very high risk of serious injury because they are more susceptible to injuries than younger people. The risk of serious injury is present even for low speeds on impact [50], [51]. This is a consequence of ageing and how it influences sensory, perceptive, cognitive and physical capability leaving older people less able to deal with traffic situations. Crossing the road is a particularly acute problem as well as the ability to estimate the distance between cars and the speed [52], [53]. A study by Sheppard and Pattinson involving [54] older pedestrians shows that crossing the road poses difficulties. These include failure to spot an oncoming vehicle or misjudging vehicle speed. Different studies suggest that more than one third of older road users report problems when they are pedestrians [55], [56]. Other studies show [57] that about 30% of people aged 65 and older have some kind of disability.

### 3. Problem identification

Road accident and demographic analyses were used to identify Poland's share of accidents involving older people as well selected causes, locations and circumstances of those accidents. A division was made into pedestrians and drivers. Figure 1 shows a forecast of Poland's population structure. As we can see, until 2060 the number of people aged 65 and older (older people) will grow. With 2015 as the baseline, 5.8 million will grow to reach 11.3 million in 2060, a doubling of the number. To analyse the statistics a 2018 police report was used [58]. By analysing safety for the different age groups relative to population, we can see that older people are most at risk of death in a road accident (Figure 2). For 949 fatalities, the fatality rate is 150 deaths per 1 million population. This is also the highest number of victims alone. As regards injuries, at 7341, the rate is 1164 victims per 1 million population. A higher rate can only be seen for the age group 15-24 (1866 injuries per 1 million population).

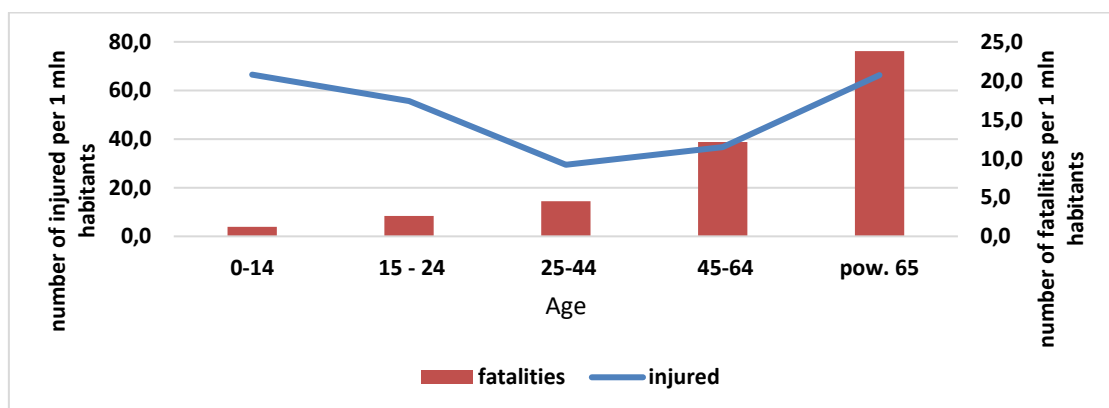


**Figure 1.** Forecast of Poland's changing population structure until 2080

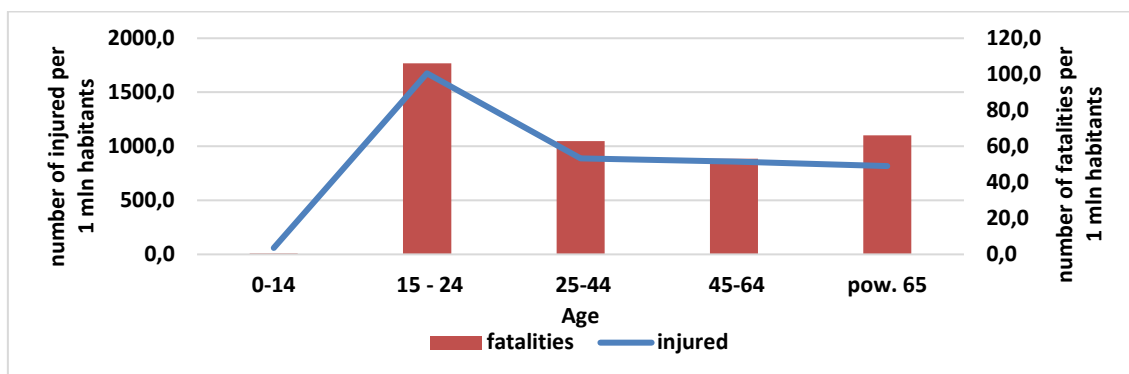


**Figure 2.** Demographic rate of accident risk and accident victims by age group

Figures 3 and 4 shows the demographic rates for people who have caused a road accident by age and role, i.e. driver and pedestrian. As regards pedestrians older people are a clearly marked group – 23.8 victims per 1 million population. In the case of injuries the rate for older people is practically the same as for the 0-14 age group. Accidents caused by older people as pedestrians in 2018 claimed 150 lives and 418 people were injured. As drivers, older people causing an accident are the second largest group for the demographic rate (following the 15-24 age group) with 66 fatalities per 1 million population. There were 417 people killed in accidents caused by older people.

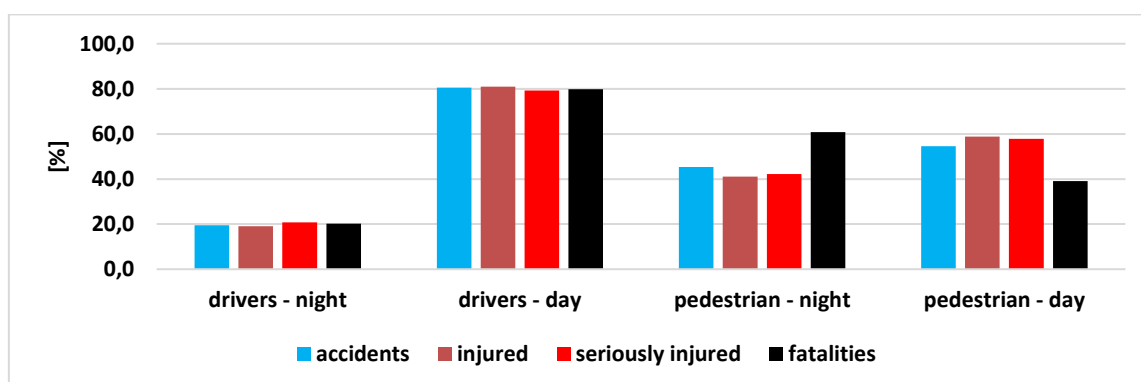


**Figure 3.** Demographic rate of accident risk and the victims by age groups – pedestrians causing accidents



**Figure 4.** Demographic rate of accident risk and the victims by age groups – drivers causing accidents

Accidents caused by older people between 2015 – 2017 were used to analyse crashes by time of day, location, type of accident and other causes. Figure 5 shows an analysis of the time of day. It is apparent that as much as 60% of accidents caused by older pedestrians happened during the night. This shows that lighting, especially at pedestrian crossings, may not be sufficient for older people. In the case of drivers causing accidents, night-time accidents represent about 20% of fatalities caused by all drivers in this age group.



**Figure 5.** Time of accidents involving older people

As regards accident locations, drivers and pedestrians cause accidents on the road (79% and 86% respectively) and at pedestrian crossings. Older drivers who are at fault caused 20% of accidents caused by this age group killing 11% of fatalities. As regards older pedestrians who are at fault 14% of accidents were caused by this age group killing 11% of fatalities. It is clear from the numbers that efforts are needed to improve pedestrian crossing safety. Analysis of type of accidents caused by older drivers shows that side crashes are the most frequent – as much as 41% of accidents with 41% of fatalities are caused by this age group. The other types of accidents include hitting a pedestrian (25% of accidents and 14% of fatalities) and head-on collisions killing 22% of fatalities. Figure 6 and 7 show the causes of accidents caused by older drivers and pedestrians. In the case of drivers the main causes include: failure to give way (34% of fatalities), wrong manoeuvres such as bypassing, driving past, turning, overtaking, lane changing (19% fatalities), wrong speed for the conditions of traffic (15%) and failure to give way to a pedestrian at a pedestrian crossing (10%). In the case of pedestrians the causes include carelessly stepping onto the road in front of an oncoming vehicle (51% of fatalities), crossing the road where it is illegal (17%), carelessly stepping onto the road from behind a parked vehicle (11%) and crossing the road on a red light (9%).

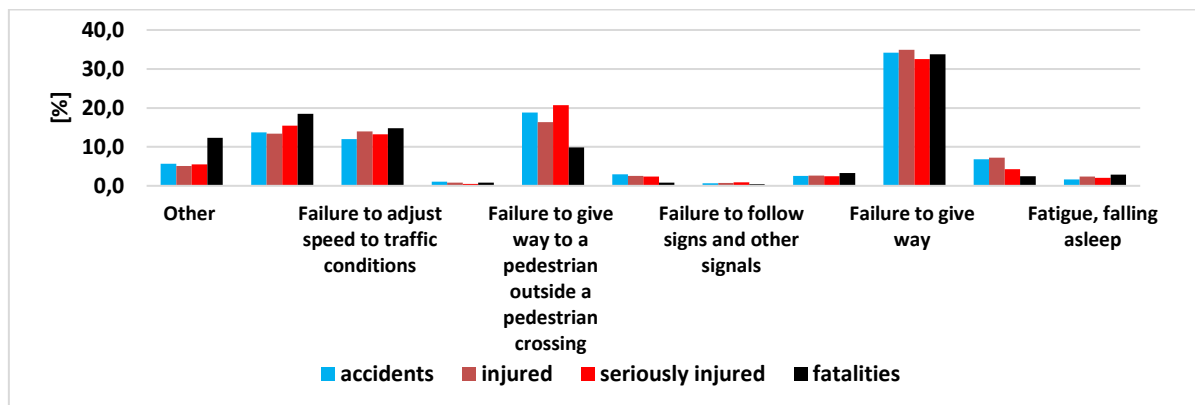


Figure 6. Causes of accidents caused by older drivers

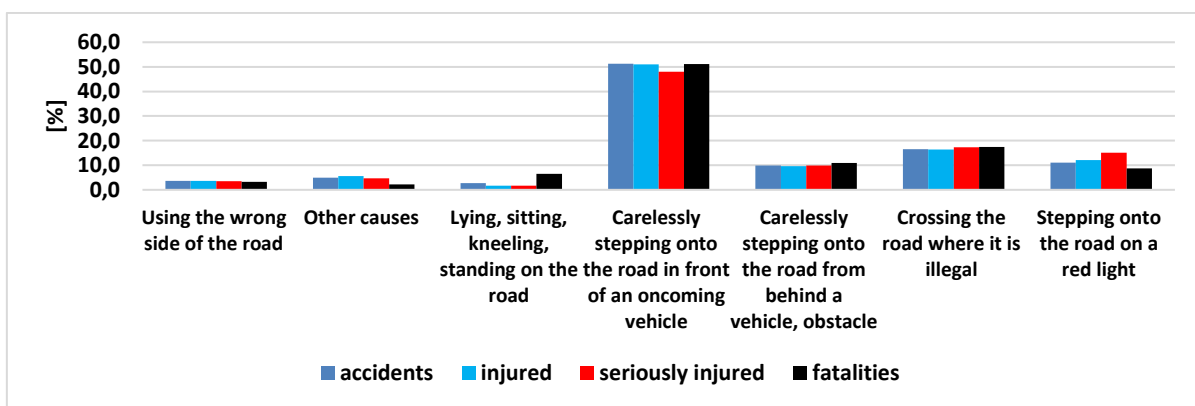


Figure 7. Causes of accidents caused by older pedestrians

#### 4. Methods for solving the problems

In order to improve the safety and mobility of older road users a comprehensive and pro-active strategy is required to deal with measures at EU, national, regional and local level. A European Commission report [8] divides the measures into the following groups:

- Infrastructural interventions;
- Education and training;
- Enforcement;
- Modern in-vehicle technologies.

A key priority is to ensure that the package of measures is based on a “design for all” approach (universal design) because it takes account of the specific needs, opportunities and limitations of different road users. As a result, these measures will not only enhance the road safety and mobility of older people; all road users will also benefit. As regards infrastructural interventions, priority should be given to: separating motorised traffic from pedestrians and cyclists (especially where traffic is intense and speeds are high), introducing low speed zones in built-up areas and around shops and services, implementing self-explaining and forgiving roads, reducing conflicts at intersections and pedestrian crossings in particular, improving lighting (especially for pedestrian crossings), implementing ITS solutions and introducing standards for old age-friendly road design. Education and training measures have these top priorities: training the elderly in recognising their deficits in road traffic and adjusting their behaviour, introducing standardised medical protocols to systematically assess the influence of age-related illnesses, functional limitations and prescribed medication on driving



abilities. Key to enforcement measures is adopting a uniform approach in EU countries concerning the decision on fitness to drive. The main measures involving modern vehicle technologies include: assessing the effectiveness of advanced vehicle technologies for older drivers, training older drivers on the effective usage of modern technologies and developing driver assisting systems.

## 5. Conclusions

The presented results of the demographic analysis indicate that the share of older people in Polish society will grow in subsequent years. This has a significant impact on safety in road transport. The age group of 65 and older is at a particular risk of being involved in a road accident. This applies mainly to pedestrians who are accident fatalities and drivers when they cause an accident. The elderly is currently ranked second among the perpetrators of road accidents. A larger share in accidents is recorded only in the 15-24 age group. Analysis of the accident circumstances indicates that most of them took place at night. The most common cause of accidents is the enforcement of the right of way (in the case of drivers) and the entry of a moving vehicle (in the case of pedestrians).

It is now necessary to undertake strategic actions aimed at reducing the number of accidents involving older people. These activities should be undertaken at various levels of traffic safety management. Infrastructure work, educational campaigns, additional training, driving license limitations and verifications, in-vehicle technologies and ITS can compensate for older people's road traffic restrictions only to some extent. Mobility, health and quality of life are interrelated with loss of mobility leading to a poorer quality of life and poorer physical and mental health. As a result, the safety and mobility of older people should be balanced when relevant strategies are developed. Lack of appropriate response from policy-makers may contribute to an increase in the number of accidents involving older people in aging societies. At the same time, a lack of sense of security will reduce the quality of life of older residents.

## References

- [1] CONSOL. (2013) (a). Mobility Patterns in the Ageing Populations (Final technical report of WP2 of the 7th framework EC project CONSOL).
- [2] D. W. Eby, L. J. Molnar, P. S. Kartje: Maintaining Safe Mobility in an Aging Society, CRC Press Published December 22, 2008
- [3] OECD. (2012). World population ageing: 1959-2050. Paris, France: World Health Organization
- [4] D. Shinar, (2007). Traffic safety and human behaviour (First edition). Amsterdam, The Netherlands: Elsevier Ltd
- [5] M. Whelan, J. Langford, J. Oxley, S. Koppel, J. Charlton (2006). The elderly and mobility: A review of the literature. Monash University Accident Research Centre
- [6] J. Kubitzki, T. Janitzek (2009). Safety and Mobility of Older Road Users. Munich, Germany: Allianz
- [7] H. Orimo, H. Ito, T. Suzuki, A. Araki, T. Hosoi, M. Sawabe (2006). Reviewing the definition of "elderly." *Geriatrics & Gerontology International*, 6(3),
- [8] E. Polders, T. Brijs, E. Papadimitriou, G. Yannis, K. Diamandouros: ElderSafe. Risks and countermeasures for road traffic of elderly in Europe, European Commission 2015
- [9] L.T. Lam: Distractions and the risk of car crash injury: The effect of drivers' age. *Journal of Safety Research*, 33 (3) (2002), pp. 411-419,
- [10] L. Ma, X. Yan (2014). Examining the nonparametric effect of drivers' age in rear-end accidents through an additive logistic regression model. *Accident Analysis and Prevention*, 67, 129–136
- [11] C. McAndrews, K. Beyer, C. E. Guse, P. Layde (2013). Revisiting exposure: Fatal and non-fatal traffic injury risk across different populations of travelers in Wisconsin, 2001–2009. *Accident Analysis and Prevention*, 60, 103–112.
- [12] A. F. Williams (2003). Teenage drivers: Patterns of risk. *Journal of Safety Research*, 34(1),

- [13] A. F. Williams V. I. Shabanova (2003). Responsibility of drivers, by age and gender, for motor-vehicle crash deaths. *Journal of Safety Research*, 34(5), 527–531.
- [14] H. Zhou, J. Zhao, M. Pour-Rouholamin, P. A. Tobias (2015). Statistical characteristics of wrong-way driving crashes on Illinois freeways. *Traffic Injury Prevention*, 16(8), 760–767.
- [15] L. Hakamies – Blomqvist, A. Sirén, R. Davidse: Older Drivers—A Review, VTI report, 497A, Swedish National Road and Transport Research Institute, Linköping, 2004.
- [16] I. Cheung, A. T. McCartt (2011). Declines in fatal crashes of older drivers: Changes in crash risk and survivability. *Accident Analysis & Prevention*, 43(3), 666–674.
- [17] J. B. Cicchino (2015). Why have fatality rates among older drivers declined? The relative contributions of changes in survivability and crash involvement. *Accident Analysis & Prevention*, 83, 67–73
- [18] J. B. Cicchino, A. T. McCartt (2014). Trends in older driver crash involvement rates and survivability in the United States: An update. *Accident Analysis & Prevention*, 72, 44–54.
- [19] G. Li, E. R. Braver, L. H. Chen (2003). Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. *Accident Analysis & Prevention*, 35(2),
- [20] M. Janke: Age-related disabilities that may impair driving and their assessment: Literature review. Sacramento, California Department of Motor Vehicles. (1994).
- [21] A. R. Dobbs: Lessons learned through the development and implementation of an evaluation for medically at-risk drivers. Paper presented at the Road Safety Research, Policing and Education Conference, Melbourne, Victoria. (2001).
- [22] J. Charlton, J. Oxley, B. Fildes, P. Oxley, S. Newstead, M. O’Hare, S. Koppel: An Investigation of Self-Regulatory Behaviours of Older Drivers. Monash University Accident Research Centre. Report Number 208. (2003).
- [23] G. Stelmach, A. Nahom: Cognitive-motor abilities of the elderly driver. “Human Factors” 34: pp.53-65. (1992).
- [24] B. J. Gonawala, N. B. Badami, F. Electicwala, R. Kumar: Impact of Elderly Road Users Characteristics at Intersection. *Procedia - Social and Behavioral Sciences*, 12/2013, Vol.104, C, pp.1088-1094
- [25] R. Robyn, V. Ward (2008). Elderly drivers: Future challenges, *Accident analysis and prevention*, 40, 1982-1986
- [26] T. Takahiro, S. Tetsuro, I. Kazunori (2009). Prediction methods for listening score and psychological impression taking into the account hearing loss due to factors such as ageing, *applied acoustics*, 70,426-431
- [27] B. Shani, O. Tal, R. Adi, B. Avinoam, P. Yisrael. (2012). The perception of pedestrians from the perspective of elderly experienced drivers, *Accident analysis and prevention*, 44, 48-55.
- [28] L. Evans: *Traffic Safety and the Driver*. New York, Van Nostrand Reinhold. (1991)
- [29] M. Dejeammes, M. Ramet: Aging process and safety enhancement of car occupants. *Proceedings of the 15th International Technical Conference on the Enhanced Safety of Vehicles Melbourne, Australia*. (1996).
- [30] J. Augenstein: Differences in clinical response between the young and the elderly. Paper presented at the Aging and Driving Symposium, Association for the Advancement of Automotive Medicine, Des Plaines, IL. (2001)
- [31] J. Langford, S. Koppel, J. Charton, B. Fildes, S. Newstead (2006) A re-assessment of older drivers as a road safety risk, *ATSS Research*, 2006, Vol.30(1), pp.27-37
- [32] D. F. Preusser, A. F. Williams, S. A. Ferguson, R. G. Ulmer, H. B. Weinstein, 1998. Fatal crash risk for older drivers at intersections. *Accid. Anal. Prev.* 30 (2), 151–159.
- [33] J. Werneke, M. Vollrath, 2012. What does the driver look at? The influence of intersection characteristics on attention allocation and driving behavior. *Accid. Anal. Prev.* 45, 610–619.
- [34] C. J. Edwards, J. I. Creaser, J. K. Caird, A. M. Lamsdale, S. L. Chisholm, 2003. Older and younger driver performance at complex intersections: implications for using perception-

- response time and driving simulation. Proceedings of the Second International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, 33–38.
- [35] G. Ho, C. T. Scialfa, J. K. Caird, T. Graw, 2001. Visual search for traffic signs: the effects of clutter, luminance, and aging. *Hum. Factors: J. Hum. Factors Ergon. Soc.* 43 (2), 194–207
- [36] K. A. Braitman, B. B. Kirley, S. Ferguson, N. K. Chaudhary, 2007. Factors leading to older drivers' intersection crashes. *Traffic Inj. Prev.* 8 (3), 267–274
- [37] T. A. Salthouse, 2004. What and when of cognitive aging. *Curr. Dir. Psychol. Sci.* 13(4),
- [38] D. Viano, S. Ridella, 1996. Significance of Intersection Crashes for Older Drivers(SAE Technical Paper 960457)
- [39] J. B. Cicchino, A. T. McCartt, 2015. Critical older driver errors in a national sample of serious U: S. crashes. *Accid. Anal. Prev.* 80, 211–219.
- [40] E. Horikawa, R. Morizono, A. Koga, J. Horie: Elderly driving behaviour and cognitive functions – Analysis of License Renewal Course Data. IATSS Research, 2009, Vol.33(1),
- [41] Cabinet Office. White Paper on Traffic Safety in Japan 2008
- [42] M. Zbyszynski, A. Swiderski: Aggressive behavior of elderly people a road traffic safety. *Transport Samochodowy* 2-2016
- [43] S. Koppel, J. Charlton, J. Langford, Z. Vlahodimitrakou: The Relationship between Older Drivers' Performance on the Driving Observation Schedule (eDOS) and Cognitive Performance. *Ann Adv Automot Med.* 2013 Sep; 57: 67–76.
- [44] J. Chmielewski, P. Olenkowicz-Trempala: Analysis of Selected Types of Transport Behaviour of Urban and Rural Population in the Light of Surveys. Recent Advances in TrafficEngineering for TransportNetworks and Systems. 14th Scientific and Technical Conference: Transport Systems. Theory & Practice 2017
- [45] J. Oxley, B. Corben, B. Fildes, M. O'Hare, T. Rothengatter (2004). Older vulnerable road users – measures to reduce crash and injury risk. (Report 218). Melbourne, MUARC.
- [46] D. Davies (1999). Research, development and implementation of pedestrian safety facilities in the United Kingdom. (Report FHWA-RD-99-089). Washington DC, US Department of Transportation.
- [47] A. Hakkert, V. Gitelman, E. Ben-Shabat (2002) An evaluation of crosswalk warning systems: effects on pedestrian and vehicle behaviour. *Transportation Research, Part F: Traffic Psychology and Behaviour*, 5(4), 275-292.
- [48] F. Khan, M. Jawaid, H. Chotani, S. Luby (1999). Pedestrian environment and behaviour in Karachi, Pakistan. *Accident Analysis & Prevention*, 31, 335-339.
- [49] European Commission: Traffic Safety Basic Facts 2018 Pedestrians
- [50] C. Mitchell (2000). Some implications for road safety of an ageing population. *Transport trends*, (pp. 26-34). London, Department of the Environment, Transport and the Regions.
- [51] OECD (2001). Ageing and transport: Mobility needs and safety issues. Paris, OECD.
- [52] P. DeLucia, M. Bleckley, L. Meyer, J. Bush (2003) Judgments about collision in younger and older drivers. *Transport Research. Part F: Traffic Psychology Behaviour*, 6(1), 63-80.
- [53] J. Oxley, B. Fildes, E. Ihsen, J. Charlton, R. Day (1997). Differences in traffic judgements between young and old adult pedestrians. *Accident Analysis & Prevention*, 29(6), 839-847.
- [54] D. Sheppard, M. Pattinson (1986). Interviews with elderly pedestrians involved in road crashes. (Report RR98). Crowthorne, Transportation Road Research Laboratory.
- [55] R. Hjorthol (1999). Daily travel in the 90s. Analysis of the Norwegian Personal Travel Surveys from 1991/92 and 1997/98. (Report 436/1999). Oslo, Institute of Transport Economics (TØI).
- [56] A. Ståhl (1991). Mobility and accessibility for elderly and disabled in Sweden. IATSS Research, 16(2).
- [57] K. Solecka: Needs of elderly as well as mobility in the cities. *Coaches* 6/2018
- [58] EUROSTAT. People in the EU - population projections, 2015