Ph. D in Land Engineering

Driving Ability Index:
An instrument for assessing elderly people's performance

ICAR /05

Author:

Claudia Pinna

Supervisors:

Prof. Dr. Gianfranco Fancello

Prof. Dr. Paolo Fadda

Co – supervisor:

Prof. Dr. Michele Meloni

Ph.D Coordinator:

Prof. Dr. Roberto Deidda

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1. INTRODUCTION

Medical advances are resulting in the increase in life expectancy and the aging of the population is becoming a general problem. By 2025 it is estimated that over 20% of Europeans will be 65 or older and the number of over eighty-year olds will rapidly increase (European Commission, 2014). Older people play an ever more active role in society and being able to drive is necessary for their mobility needs (Lyman, 2002).

Aging causes the decline of driving related skills, so accident rates are higher for older drivers. However, being able to use the car motivates older people to maintain an active life and participate in social activities. When deprived of their driving licence, the elderly often suffer from isolation and depression so this phenomenon also has social implications. For these reasons it is necessary to recognize drivers who are potentially risky, because they no longer have the skills required to drive, from those who are still able to drive and be independent.

The aim of this study is to develop an easy to manage tool for objectively evaluating the driving ability of elderly drivers, for identifying the premature signs of any decline in physical ability and cognitive skills, and for identifying devices best suited to help them to overcome their deficits and to improve their driving abilities and stay safe behind the wheel for longer.

The Work Ability Index (WAI) is a tool already known and widely used in occupational medicine to measure the ability to work and to identify any signs of decline in work performance. During the PhD research collaborating with occupational physicians (Cagliari and Milan), we decided to adapt the Work Ability Index for the purpose of assessing the driving ability of the elderly, proposing the Driving Ability Index (DAI).

The questionnaire in its original form was used to calculate an index that measures work ability. The contents have been adapted to obtain a score and to categorize ability to drive into four quality levels: excellent, good, moderate and poor.
In order to adapt the questionnaire a pilot survey was conducted in the city of Cagliari, involving 54 drivers over the age of 65, with the collaboration of Professor Michele Meloni and Dr. Luigi Lecca.

Part of the study was conducted in the city of Newcastle upon Tyne in collaboration with Dr. Amy Weihong Guo. At this stage the questionnaire (Driving Ability Index) was adapted to British culture and its ability to evaluate and predict driving ability in elderly

drivers has been verified. In order to verify the effectiveness of the Driving Ability Index, road tests on a standard route as proposed by Justiss (2005) were conducted involving 31 drivers and 12 drivers were tested using a driving simulator, so as to compare the performance obtained in these tests with the results obtained from the questionnaire DAI.

The results obtained with the driving simulator test and in the road tests were compared with the DAI evaluation, calculated on the basis of the questionnaire responses, using Kendall's Tau test. We only found a significant correlation for women drivers, so using factorial analysis and linear regression techniques the most significant variables have been identified and a model was estimated to predict driving ability rating on a scale from 0 to 3, which corresponds to a judgment from poor to excellent.

Analyses performed in this study showed that the ability to drive depends on physical and mental abilities, on driving behaviour and lifestyle. For this reason upon licence renewal all these elements need to be evaluated and not only one skill as generally occurs (usually eyesight).

The proposed model explains 70% of the variance in the ability to drive and requires few input variables to be calculated, so it is easy to apply and may be used for the renewal of driving licences to identify drivers who may be potentially risky, owing to poor driving skills.

The model also allows one to identify drivers with moderate driving ability and thus still able to drive, be it with some difficulty, but who need some kinds of aids. Responses to item 3 of the questionnaire, that highlights drivers' medical conditions and physical impairments, provides indications as to the most suitable in-vehicle aids to help elderly drivers overcome their deficits and continue to drive safely for longer.

This thesis is divided into eight chapters.

This chapter, the introduction, briefly describes the objective of the research, the methods applied and the results obtained.

Chapter 2 concerns human factors in transport and the study of the topics aimed at reducing accidents through the design of human-compatible systems

Chapter 3 describes the background of the study and the results of other studies that formed the basis of this research. We have addressed the general problems of aging, diseases typical of old age, driving behaviour of older drivers, driving offences, difficulties

when manoeuvring and driving, procedures for licence renewal, gender differences and techniques for driving ability assessment in the elderly.

In Chapter 4 the adaptation of the work ability index is described and the results of the pilot survey performed in Cagliari are analysed.

In Chapters 5 and 6 the activities conducted in Newcastle are described. Chapter 5 the road test is described and the results compared with those obtained from the DAI questionnaire, while Chapter 6 describes the tests conducted with the driving simulator, comparing these results with the scores obtained in the questionnaire that was distributed online.

Chapter 7 concerns the factor analysis conducted to identify the latent factors that explain the ability to drive. By means of multiple linear regression techniques, a model has been estimated to assess the driving ability of the elderly drivers that ranks driving ability from 0 (poor) to 3 (excellent).

Chapter 8 presents the conclusions, the results of the research and possible future developments on the basis of the results obtained.

2. HUMAN FACTORS IN TRANSPORTATION

Human factors are concerned with the design of systems compatible with the capabilities, limitations, characteristics and stereotypes of users.

The International Ergonomics Association defines ergonomics or human factors as follows: “Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance” (International Ergonomics Association, 2014).

The aim of human factor studies is to bring to light those design characteristics and layout that reduce the risk of accidents caused by a deterioration in driving performance. In the beginning human characteristics related to physiological aspects (health, attitude) were addressed, then the analysis was extended to the methods of interaction of man with the specific working environments (psychophysical aspects and decision - means - environment - organization).

In active safety, many factors are considered which directly affect the level of safety of passengers. Other factors affect driver’s performance, so indirectly, as a consequence they also affect the safety.

One of the factors that most affects safety and also comfort of a transport system is the compatibility of the required tasks with the characteristics, capabilities and limitations of drivers. For this reason the human element must be considered a component of the system, and is a critical feature of all aspects of the design. Thus the human factor must be integrated into the design of transport systems, as it provides those criteria, parameters and scales of evaluation of the effects of different design solutions.

Driver performance is the primary cause of accidents, in fact over 80% of accidents in private and public land transport are caused by human error.

Research on human factors and particularly on active safety, takes into account a wide range of human reactions that vary according to gender, level of fatigue, culture, social norms and age, to enable the design of human-compatible systems.

Physical ability and cognitive skills deteriorate with age and mobility needs change. The aging world population poses real challenges and the design of systems compatible with the characteristics of elderly drivers and the study of the physical and cognitive abilities required to drive safely have become important goals in human factor research.

Drivers have to manage multiple stimuli from the environment and this input should be designed so as to be rapidly received and generate the appropriate driver reaction in a time frame compatible with their physical characteristics.

As these skills decline with age, it is important to identify what characteristics are required for driving, in order to identify those drivers who are able to drive safely and those who need to be assisted by means of appropriate in-vehicle devices that can compensate for their deficits, enabling them to continue to use their vehicle in safe conditions.

3. BACKGROUND

3.1 Aging of the world population

The aging of the world's population is the main demographic trend observed over the last century. This phenomenon is due to the combined effect of the reduction in fertility and in birth rates and the increase in life expectancy.

The 2013 World Population Ageing report, produced by the Department of Economic and Social Affairs Population Division of the United Nations, shows that total fertility rate has halved over the last 50 years, decreasing from 5.0 children per woman in 1950-1955 to 2.5 children per woman in 2010-2015 (Figure 1). This trend is expected to continue over the next years to reach an estimated rate of 2.2 children per woman for the five years 2045-2050.

In most developed countries the reduction in the fertility rate in the last half of the 1900s was greater, dropping from a rate of 2.8 children per woman in 1950-1955 to 1.6 in 2000-2005. However, over the next five years the rate increased slightly to 1.7 children per woman in 2005-2010. The UN predict a further slight increase for the five years from 2045 to 2050 with a rate of 1.9 children per woman.

This value is still below the substitution level, which is 2.1 children per woman. The phenomenon has a different trend in the less developed regions, where the fertility rate was 6.1 children per woman in 1950-1955 to decrease significantly between 1970 and 1990, to reach a rate of 2.7 in the period 2005-2010. Although the fertility rate in less developed regions is still well above that of the more developed countries, in the period 2045-2050 it is expected to decrease further (2.3 children per woman).

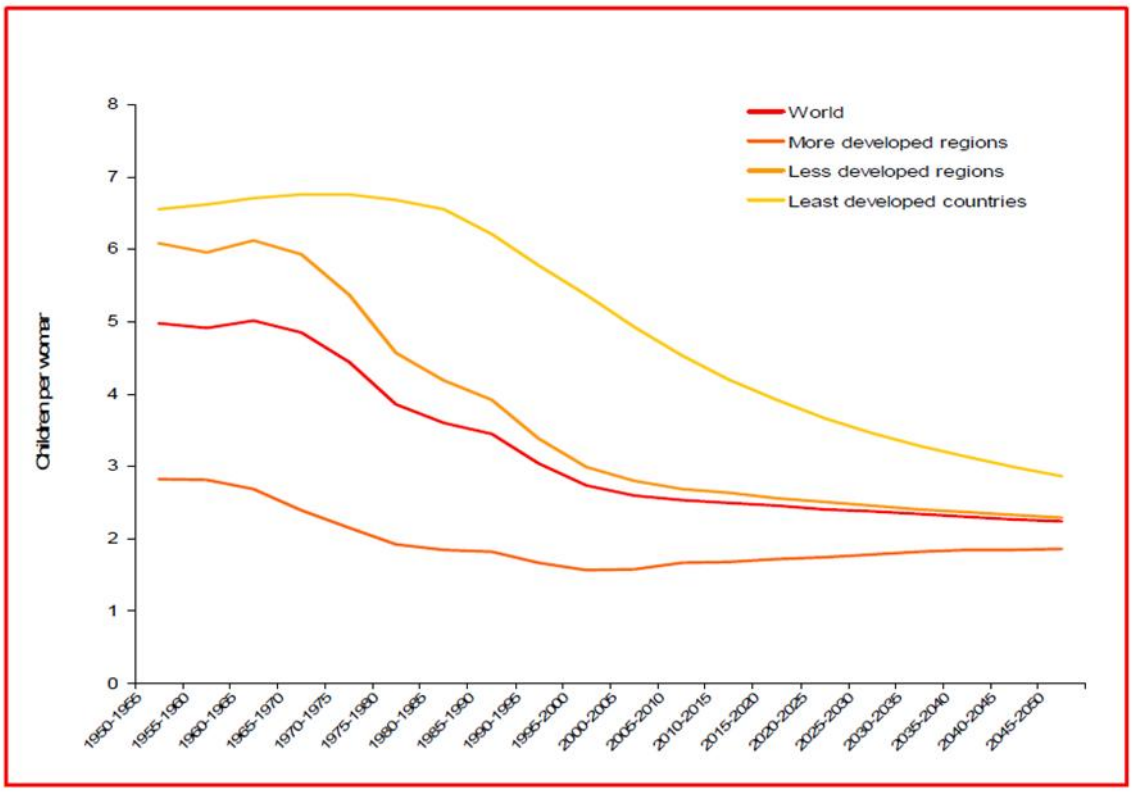

Figure 1 – Total fertility rate 1950 -2050 – Source : World Population Ageing 2013 report UN.

Birth rate is closely related with fertility rate and population size. During the twentieth century the number of births in the world increased decade by decade. The number of births is about 140 million per year and is expected to decline before the end of the century, reaching 130 million births per year (Figure 2). The combined effect of the reduction in the number of births and the increase in life expectancy is significantly changing the shape of the demographic pyramid with a general aging of the population. The number of births in most developed nations remained stable after declining during most of the second half of the twentieth century and it is this phenomenon that is at the root of the aging population in these areas of the world.

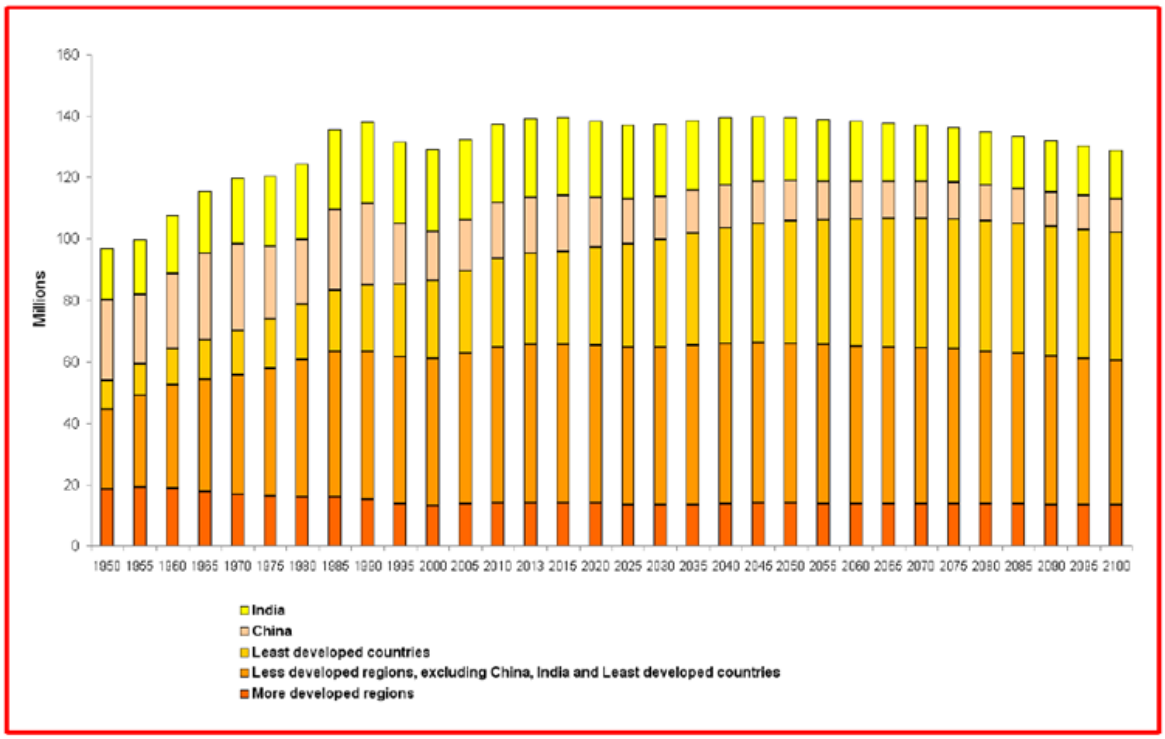

Figure 2 Annual number of births 1959-2100 – Source : World Population Ageing 2013 report UN.

The increase in average life expectancy is one of the greatest human achievements, and can be attributed to medical advances and improvement in the quality of life.
Human lifespan will continue to grow worldwide in the coming decades. In 1950 it was 65 years in the more developed countries compared to only 42 years in the less developed regions. In the period 2010-2015, it is estimated that life expectancy will reach 78 years in the more developed countries and 68 in the less developed ones, increasing in the period 2045-2050 to 83 and 75 years respectively.
In 2010-2015, globally, people aged 60 will live for another 20 years and for the period 2045-2050 on average for another two years. These data are shown in the following chart drawn up by the UN (Department of Economic and Social Affairs Population Division UN, 2013).

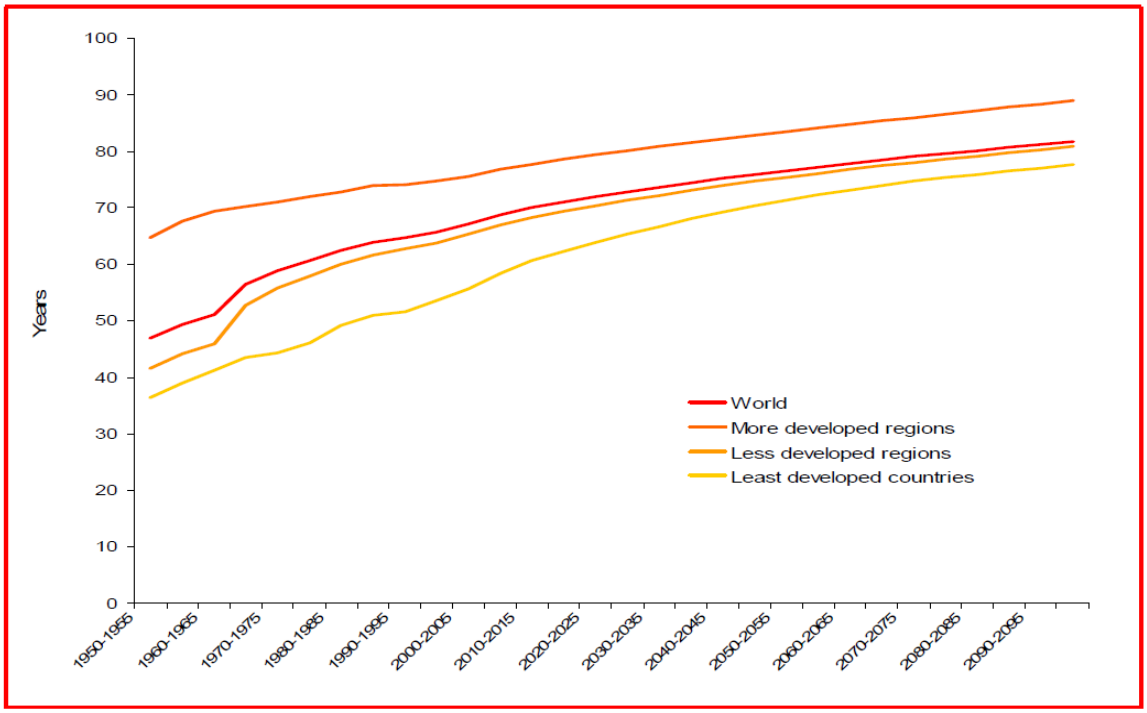

Figure 3 Life expectancy at birth 1950 -2050 – Source : World Population Ageing 2013 report UN.

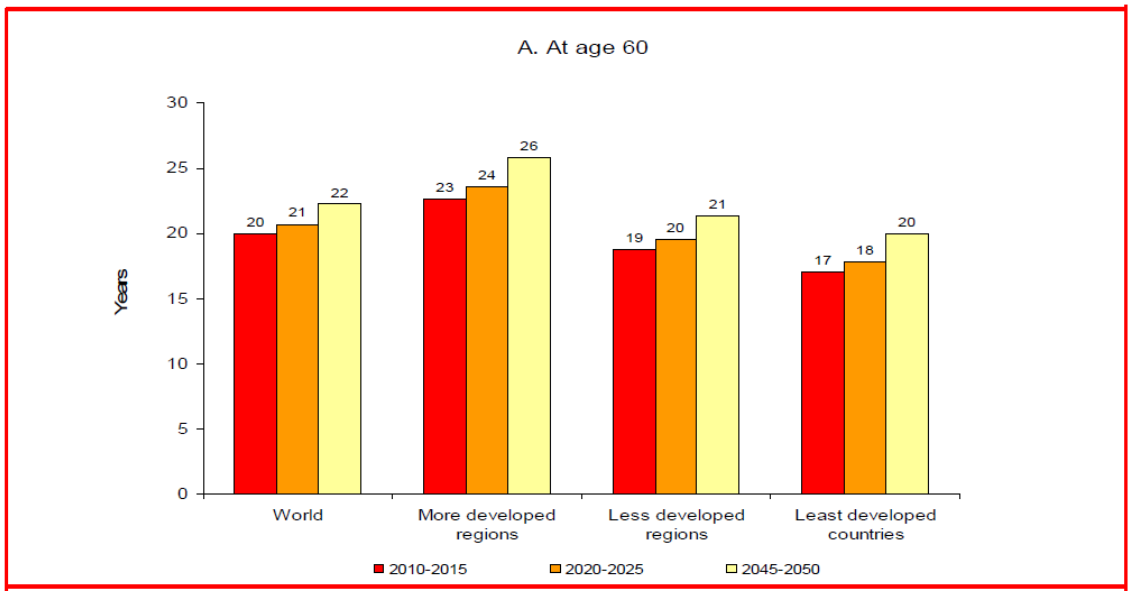

Figure 4 Life expectancy at age 60 2010-2015, 2020-2015 and 2045-2050 – Source : World Population Ageing 2013 report UN.

3.2 Mobility related aspects of aging

As shown in the previous paragraph individuals older than 65 years are the fastest growing segment of the population and also tend to stop driving increasingly later. The opportunity to drive is still one way for seniors to maintain their independence and participate in social life, especially in rural or remote areas, or where public transport does not meet their mobility needs. Being able to drive greatly affects the social life of the elderly

who are at risk of isolation and depression (Fonda, Wallace, Herzog, 2001). Thus this problem also has social effects.

Driving requires the ability to understand relevant information and ignore irrelevant information within complex visual scenes: the speed with which visual information is processed may be an important factor for successfully managing dangerous situations.

The physical conditions and medical, cognitive and sensory functions of a driver are factors affecting the ability to drive and therefore influence the likelihood of an accident. This occurs particularly in old age, because aging causes a decline in many cognitive skills that are important for executing complex tasks such as driving. With increasing age there is a greater propensity for disability due to the deterioration of physical and cognitive abilities and the onset of diseases typical of old age. 54.5% of older people have at least one disease and 74% of people older than 85 years, have at least one disease or disability (Ficke, 2003). The cognitive and physical changes of an individual caused by aging can impair the ability to drive and consequently increase the risk of an accident.

3.3 Accident risk for older drivers

Accident rates are higher for older drivers and increase exponentially for drivers over the age of 75 (Guerrier, Manivannan, Nair, 1999). Incidents involving older people are characterized by more serious injuries due to deterioration of their physical condition and the greater rigidity of their skeletal structure. A recent study estimated that for drivers aged between 70 and 74 years the likelihood of being killed in an accident is twice that of drivers aged between 30 and 59, while for 80 year olds the risk is five times greater (Li, Braver, Chen, 2003). These higher mortality rates are due to the elderly's physical fragility and reduced recovery, that make a simple incident, a potential fatal accident.

The fragility of a group of drivers is shown by the difference in their mortality rates and injury rate. As can be seen from the diagram below, drivers over 75 years old have the second highest mortality rates; only the youngest group (aged 18 and 19) have a higher mortality rate. The figure on the left shows the well-known U-shaped pattern of mortality rates: for young people it is high, decreasing to the minimum value for 40-60 year olds, to then peak for drivers of over 75. Changes in rates of injury are shown in the figure on the right; the younger age groups exhibit a similar trend to the previous figure, but this changes for older drivers. The accident rate is lower than the mortality rate as their physical fragility means they are more likely to be killed if involved in an accident.

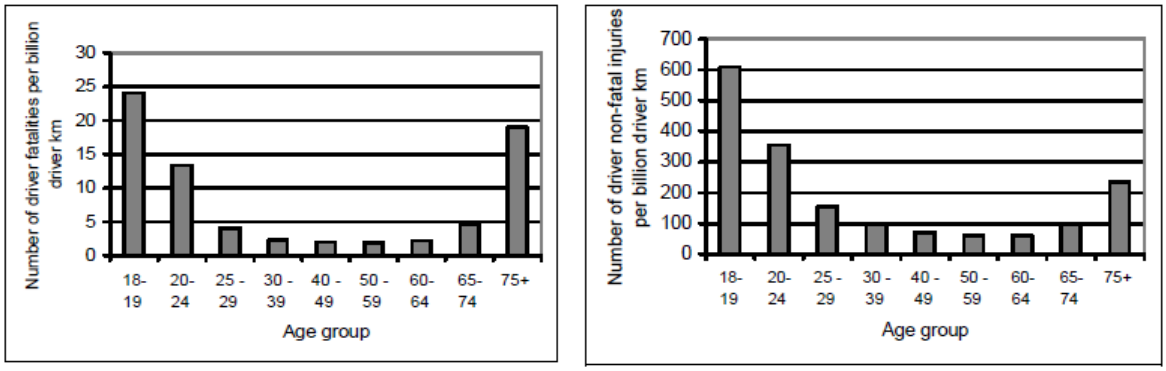

Figure 5 Number of driver fatalities and non-fatal injuries– Source : SWOV/ Institute for Road Safety Research

Elderly drivers are often involved in specific types of accidents, in situations such as junctions, lane changes and moving out of a parking space. This had led to several prejudices about older drivers.

Not all authors consider the elderly high-risk drivers as their accident rates are influenced by the reduced mileage driven. Generally, drivers who make longer trips have lower accident rates per mile than drivers with low mileage. Elderly drivers usually travel short distances so their accident risk is overestimated (Langford, 2006). It is important to note that not all elderly drivers are dangerous: on the contrary, they behave very cautiously and compensate for their physical disadvantages with their experience. This has highlighted the need to identify which cognitive, sensory, physical and motor factors are enablers for safe driving, in order to identify older people who are potentially at risk.

3.4 Travel habits of older drivers and implications for mobility

With aging, the way people use the car changes as do their individual mobility needs. In 2006, young people aged 18 to 29 years numbered 4.025.980 in Italy, due to the aging population, and by 2016 this age group will have decreased by around 11% (ISTAT). The oldest group, aged between 55 and 80, will increase by 9%. As a result, motorists are getting older and as they age they change their lifestyle, using their cars less. In some cases the elderly find they have to replace their current car with a vehicle more suited to their needs (CENSIS, 2007).

In Italy, for all age groups, the private car is the means of transport used for almost all trips (89.1%). Younger drivers use the car most, while with age car use decreases, the elderly travelling more frequently by urban public transport and walking more (CENSIS, 2007). The over 65 year-olds tend to use public transport even more but to walk less, due to impaired physical abilities, but in any case more so than the younger age group. However, in

the future, elderly drivers needs will be similar to those of 45-65 year olds, due to longer working lives making the lifestyle of a 75 year old like that of a current 65-year old. The new demographic changes will transform private mobility. In old age, the approach to mobility becomes increasingly intermodal, though with aging the inconvenience associated with the use of public transport increases.

As emerges from the ACI-CENSIS report (2007), the choice to use public transport is decidedly limited. For older users the reasons are attributable to the lack of comfort of public transport vehicles (45.3%), the lack of connections that accounts for 38% of inconvenience and the excessive distance to the bus stop from home is a problem for 14.7% of users.

Table 1 Ttransportation mode for different age groups in Italy – Source: Aci Censis 2007

Transportation mode	18-29 years old	30-44 years old	45-64 years old	Over 65 years old	Total
Bus/train/metro in urban area	19.7	16.2	20.4	22.40	18.9
Bus/train in suburban area	13.7	9.0	13.4	13.50	12.0
Car	86.3	90.3	87.7	80.4	86.5
Motorbike/scooter	37.8	20.3	6.6	1.00	17.7
Bike	18.5	16.9	18.0	10.4	17.8
On foot	16.5	26.2	33.1	20.3	27.3

The reduction of car use by the elderly is high. As can be seen from the following table (Report ACI-CENSIS, 2007), on average, in 2006, the car was used 5.0 days weekly, compared with 5.1 in the previous year. The number of days of use of the car during the week decreases with age. Drivers aged between 45 and 65 years use the car 4.9 days a week, while over 64 year-olds drive 4.6 days a week, younger drivers 5.3 days a week.

Table 2 Driving days a week for different age groups in Italy – Source: Aci Censis 2007

Average	Age				Total
	18-29 years	30-44 years	45-64 years	over 65 years	
Driving days a week	5.3	4.7	4.9	4,6	**5.0**

In recent years, 23% of Italians use the car less due to the cost of fuel. In the over 65 age group, the rising cost of fuel resulted in a reduction in car use for 27, 5% of questionnaire respondents. The modal choices of the elderly depend on a growing environmental awareness and in particular on the need to contain the costs of mobility, because in the transition to retirement, disposable income is reduced.

3.5 Driving habits and behaviour

Compared to younger drivers, older drivers use the car less and travel on average at lower speeds. From the analysis of accidents and driving behaviour, it appears that older drivers are more likely to change their driving habits, in order to avoid particularly difficult situations such as rush hour, night driving or poor road condition, especially the over 75 year-olds.

The elder are aware of their limitations in driving, and are thus prudent and rarely they commit traffic offences.

To facilitate managing the complex situations that occur when driving, the elderly reduce their driving speed. When this is not possible, they may be forced to perform manoeuvres under pressure within time periods that are not compatible with their abilities.

The main changes observed in aging are:

• Reduction in mileage;
• Change of lifestyle and reduction of the use of private vehicles;.
• Decrease of the symbolic value attributed to the car;
• Increased difficulty driving;
• Reduction of driving pleasure (72.2%).

Moreover, they take a lot longer than young drivers to cross junctions (Fancello, 2013). Changes in the use of the car are also influenced by gender. All aspects analysed appear much more pronounced for women than for men (CENSIS, 2007).

3.6 Accidents

Several surveys have shown that accidents involving older drivers happen mostly at junctions. These create particularly difficult situations for elderly drivers, as a large number of stimuli are involved, obliging them to perform a variety of tasks (controlling the flow of vehicles and pedestrians, assessing the maneuvering areas etc.). When these actions are concentrated into a short space of time an overload may occur, resulting in the decline of mental and physical abilities and in a greater risk of error.

Accidents caused by elderly drivers often occur in the early hours of the morning or late at night, owing to reduced visibility. However they are rarely involved in accidents caused by speeding, risky overtaking or driving while intoxicated or generally due to dangerous behaviour (EU Road Safety, 2011).

3.7 Manoeuvres and junctions

Older drivers often find some traffic situations remarkably complex, particularly left turns, which entail yielding to oncoming traffic, signalized junctions and those regulated by stop signs (Blomqvist, 2004), merging on a ramp and changing lanes. They also encounter considerable difficulties driving at night.

To merge from a ramp, drivers need to accelerate in order to adjust their speed to the traffic flow and find a sufficient gap to enter between vehicles. These tasks require the ability to estimate the speed of approaching vehicles which is reduced for drivers who have problems with their vision.

The same abilities are required for left turns where the driver has to yield to oncoming traffic. Often in this situation elderly drivers, readily cross the junction without giving priority to vehicles coming from the opposite direction, because they feel they are at risk waiting in the middle of the junction. The largest number of accidents involving elderly drivers happen during this manoeuvre.

Changing lanes requires drivers to quickly assess the speed of approaching vehicles. In this case the task is more complex than in the previous cases, as the only information is that provided by the rear view and side mirrors. This manoeuvre is less dangerous because it is optional, and often elderly drivers prefer to avoid changing lanes remaining where they are.

These results emerged in a study (Fancello, 2008) in which the behaviour of older drivers in Kentucky (USA) and in Sardinia (Italy) has been compared with the aim of bringing to light any similarities or differences between Italian and American drivers and the motivations that drove them. These differences could be attributed to driving habits as well as to different infrastructure, vehicle models and traffic regulations in the two countries. The data were collected through 235 interviews. Drivers were interviewed about their health conditions and driving behaviour in specific manoeuvres, such as merging from a ramp, changing lanes, turning left and driving at night.

The study also showed that older drivers often change their route to the same destination to avoid complex or potentially hazardous situations.

In a study conducted in 2002 accident data in Kentucky, from 1995 to 1999 were analysed in order to assess the most difficult manoeuvres and those that are likely to cause accidents. The database was analysed using logistic regression techniques and the results indicated that older drivers are more likely than young people to be involved in an accident during specific maneuvers such as turning left, turning across traffic and changing lanes on high-speed

roads. Older men are less dangerous than women and the presence of a passenger in the vehicle with elderly drivers helps to create a safer driving environment (Chandraratna et al., 2002).

Another study conducted in 2012, examined the difficulties perceived by elderly drivers negotiating a roundabout, using eye-tracking techniques. It was found that older drivers encounter major difficulties at roundabouts due to the large number of stimuli from the environment, obliging them to select and evaluate their importance. If too many stimuli are involved this can create an overload. These drivers probably do not fully understand roundabout rules and look out for cars coming from the right rather than those from the left, as they do at normal junctions (Pinna, 2011; Fancello et al., 2012).

3.8 Offences

Young people commit far more traffic offences than other road users, especially older drivers who are unlikely to violate traffic rules (Blomqvist, 2004) and to drive under the influence of alcohol or drugs. As people become older they tend to obey traffic rules and regulations more. Table 3 shows the offences committed by ACI members in 2005, divided by age group. As can be observed older drivers have a more conservative approach than young people and commit the fewest violations. In particular no one over 65 was found driving under the influence of alcohol or on the hard shoulder.

Table 3 Offences committed in 2005 by age group (sample ACI, 2006)- Source: ACI CENSIS Report 2007

Offence	18-34 years old	35-44 years old	45-54 years old	55-64 years old	Over 65 years old	Total
Speeding	40.6	31.7	22.2	30.6	13.2	24.2
Parking in a prohibited space	34.1	36.0	32.0	20.5	17.0	23.6
Seat belt offences	36.7	28.8	22.4	11.6	12.4	16.8
Using a hand-held mobile phone while driving	23.1	17.9	12.5	10.4	8.9	15.7
Parking alongside another vehicle or on the pavement	22.1	15.0	13.5	17.8	11.6	12.8
Traffic light offences	19.3	12.4	0.8	9.0	3.5	8.5
Not using indicator	15.7	10.7	9.8	6.5	3.5	8.0

U turn	22.9	15.5	3.9	7.7	1.6	7.6
Failure to give way	14.7	14.7	9.8	1.4	5.4	5.9
Overtaking on the right	10.1	9.5	2.9	1.4	3.5	4.7
Driving in pedestrian area	5.5	4.3	1.9	1.5	0.7	2.0
Drink driving	7.3	1.7	2.0	1.3	0.0	1.4
Going the wrong way	1.8	2.6	2.0	1.5	0.7	1.1
Driving on hard shoulder	1.8	1.7	1.0	1.3	0.0	0.8

3.9 Road signs

A 1994 study found that elderly drivers take 34% more time to identify a visual stimulus than middle aged drivers and 70% more than young drivers (Deward, 1994). This forces them to slow down to perceive signals that can provide useful information. 55.4% of drivers interviewed in a study in 2006, claimed they had no problems reading road signs. Note that 19.2% of the respondents encountered difficulties in the perception of variable message signs and 16.6 % perceiving road marks.

The same sample was asked in what way the perception of traffic signs could be facilitated. 47.9% of respondents stated it was sufficient to increase the size of the signs while male drivers believed that larger and better lit signs could improve perception.

Even the reading time required for the perception of variable message signs is strongly affected by age. Kim (2009) estimated the time needed to perceive messages according to vehicle speed and driver age.

In 2014, during laboratory tests, drivers were shown a variety of driving scenarios in which variable message signs appeared. The results indicated that older drivers have longer reading times than young drivers and this difficulty increases with speed (Fancello, 2014).

3.10 Self-assessment of driving ability

In order to evaluate whether older drivers properly assess their own driving performance and to determine whether this ability is affected by their cognitive ability, in 2005 tests were conducted on 152 over 65 year-olds. Drivers were first asked to self-evaluate their driving performance compared to their peers. They then took a cognitive MMSE test (Mini-Mental State Exam) and a driving simulator test.

65% of drivers tested believed they drove better than their peers, while 31.9% judged themselves to be as capable as their peers. The results showed that 50.0% of those who thought they drove "a little better" than the others and 52.9% of those who thought they drove "much better" had a dangerous driving performance.

Drivers who think they drive at least a little 'better than their peers were four times more dangerous than those who thought they were similar to or worse than other drivers. There was no significant difference in MMSE between groups with different self-evaluation ($p = 0.76$), cognitive ability is not related with the ability to self-assess driving performance (Freud, 2005).

3.11 The cognitive and physical changes caused by aging

The abilities required for driving are cognitive, sensory and physical and they are prone to physiological decline due to age (Anstey et al., 2005).

Psycho-gerontology has demonstrated that some skills strengthen with aging. The intellect can continue to improve in old age, becoming slower but more reflective. Despite it occurs compensation skills, people's senses change, but with adequate training that takes into account these characteristics, the capabilities can be maintained.

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3.11.1 Cognitive abilities

Cognitive abilities include attention, memory, perceptive abilities, reaction speed, ability to plan and schedule, efficiency and intellectual concentration. All these skills are required for driving, a complex cognitive task.

In a study conducted in 2011 a multi-factor model was developed to explain the role played by cognitive and visual skills, using a set of standard tests for assessing driving ability. Visual acuity and contrast sensitivity were measured. The widely used field of vision test (UFOV) was performed to measure the visual field, as well as two other tests: "Hazard Perception Test" (HPT) and "Hazard Change Detection Task" (HCDT) test for assessing the ability to perceive risky situations.

This study involved 297 drivers between the ages of 65 and 96. Factorial analysis indicated that cognitive and visual skills explain 83-95% of the variance in driving ability. It was also found that the ability to drive decreases with age and this decline is due to the

deterioration of cognitive abilities such as management and storage of visual-spatial information, especially in a short space of time (Anstey, 2011).

3.11.1.1. Attention

Attention is a selection process whereby one stimulus is selected over another, thus filtering out any information irrelevant to the task performed. Selective attention is strongly affected by aging. Cherry (1953), who pioneered research into selective attention, tried to understand why just a few, out of a multitude of environmental stimuli, are selected and others are ignored.

Divided attention is the ability to pay attention to several things at once, this ability affect crash involvement (McKnight et al., 1999), such as selective attention (De Raedt et al. 2000; McKnight et al., 1999; Marotolli et al. 1998) concerns the selection of stimuli and divided attention its distribution.

A study by Hasher and Zacks (1988), showed that aging is associated with the malfunctioning of the attention processes that control access and temporary storage of information which is not relevant to the activity carried out.

Many studies have shown that with aging the attention has the same accuracy but the elderly take longer to process information (Abbate, Luzzati, Vergani, 2007).

For several years, research on older drivers was focused exclusively on assessing visual acuity, but this needs to be analysed simultaneously with cognitive abilities. A study conducted in 2003 examined the changes in the visual and attention abilities of drivers due to aging. For this purpose two questionnaires were developed: the first aimed to identify drivers with a high likelihood of accidents, through the assessment of functional capacity and the second aimed to identify appropriate strategies to maintain or restore functional ability.

One of the most interesting results of this study was that using this approach, older drivers become aware of their difficulties and gradually accept to reduce car use (Gabaude, 2003).

3.11.1.2. Perceptual and visual-spatial skills

Perceptual skills include visual perception, perceptual speed and visual-spatial abilities. The visual search process is influenced by perceptual strategies and these involve perceptual grouping and the suppression of distractor elements (Davis, Fujawa, Shikano, 2002).

It is possible to assess visual perception by means of the "Movement perception test". The results of tests conducted in 2000 showed a high correlation with the ability to drive and with crash involvement (De Raedt et al., 2000; Marotolli, 1998; Stutts, 1998).

Perception speed can be measured by identifying a target within a disturbed field (McKnight et al., 1999).

Visual-spatial skills can be determined using the '"Hooper organisation visual test" (Marotolli, 1998), the "missing pattern" (McKnight et al., 1999) and the "paper folding test" (De Raedt et al., 2000). The latter is the most complex and the one that shows the greatest correlation with driving performance and crash involvement. During this test, the patient is asked to imagine a piece of paper that has been folded with holes punched at appropriate points. He has to imagine how the holes are arranged on unfolding the piece of paper (De Raedt et al., 2000).

3.11.1.3. Speed and reaction time

Processing speed and reaction time are characteristics necessary to successfully negotiate risky situations that may occur during driving. It is important to choose the right procedure, but crucial that making the decision and the reaction occur with a sufficiently short space of time. The elderly react more slowly than young people and in a dangerous situation this can lead to misjudgement, resulting in response errors. However, older drivers often compensate for this deficit with driving experience.

The changes due to aging need to be acknowledged and addressed, and appropriate action taken that considers the needs of older drivers.

Reaction time can be evaluated by means of the "number tracking test" adopted by Marottoli in 1998.

Processing time plays an important role and indeed speed is a major risk factor (Skyving, Berg, Laflamme, 2009; Odenheimer et al.1994). In order to manage the complex situations that occur when driving, the elderly tend drive at slower speeds. When this is not

possible, they can be forced to perform maneuvers under pressure, in times that are not compatible with their capabilities.

The reaction time is the time interval that elapses between the time the brain perceives a stimulus and the moment the driver takes action. Several tests have been devised for estimating reaction time such as "Respond to square" and "Respond to brake lights" used by Mc Knight & Mc Knight, 1999 who demonstrated the strong correlation between reaction time and accident risk

3.11.1.4. Memory

Memory is the mental function that captures, encodes, stores and retrieves information acquired during an experience. This is an essential skill in driving (Hu et al., 1998; Odenheimer et al.1994) drivers need to remember how to use their vehicles, the meaning of road signs and they must also remember their destination and how to get there (Colsher, 2003).

Odenheimer (1994) applied the “Wechsler Memory Scale” to assess memory. This test consists of seven subtests that assess: information, orientation, mental control, logical memory, repetition of numbers, visual reproduction and the ability to link the concepts.

3.11.1.5. Mental Status

Mental status includes the ability to judge and the ability to reason and can indicate the presence of symptoms of mental disorders.

The MMSE (Mini Mental State Examination) is a test that evaluates intellectual function and is able to detect the presence of cognitive impairment, it has been applied in several studies (Odenheimer et al.1994; Margolis et al., 2002) in order to evaluate if mental status affect crash involvement.

The test consists of thirty questions concerning seven cognitive domains. Orientation in time and space, the recording of words, attention and calculation skills, recall and language skills. These functions depend on the awareness of people's own abilities and coordination skills.

In the studies examined, no correlation was found between the MMSE results and accident risk for elderly drivers (Margolis et al., 2002) (Marotolli et al., 1998), though a correlation did exist with driving performance (Odenheimer et al. 1994).

Dementia is not a specific disease, but is a general term that indicates the general decline in mental abilities (Alzheimer's Association, 2015), which typically occurs in old age. Dementia can affect mobility and safety of drivers and there are even more drivers with dementia; for this reason, in a Cochrane Review, in order to evaluate if driving assessment facilitates continued driving and if reduces accident in people with dementia, 70 abstract and 41 full text papers have been reviewed. The findings of this study show that there is a lack of assessment methods in the transport literature for drivers with dementia (Martin, 2013),

3.11.2 Sensory functions

The sense organs are physical structures in the body, which allow interaction with the surrounding environment. These organs are composed of more or less complex structures, which are specialized in the reception of stimuli from outside or inside the body. These stimuli are converted into nerve impulses and transmitted to the central nervous system. The senses involved in driving are sight, hearing and touch.

3.11.2.1. Sight

Sight allows us to perceive light stimuli from the environment. A large part (90%) of the information required for driving is visually perceived.. Eyesight is one of the senses most affected by aging (Kline & Scialfa, 1997). Over 65% of older drivers have problems with their eyesight. Everyone's vision changes with age: a 60 year-old needs eight times more light than a 20 year-old to be able to see in the dark.

The eyes are more sensitive to glare and older people have difficulty perceiving movement at the edge of the visual field, due to a reduction in their field of vision (Crassini et al., 1988). They also find it slower to adjust focus at different distances (Butler et al., 1999) and, the minimum duration of fixation needed to identify the details of a road sign (Dewar et al., 1994). increases with age.

Characteristics that can affect driving behaviour are eye health, visual acuity, range of useful field of view, colour discrimination, depth perception and contrast sensitivity. Eby et al. (1998) found that with age a variety of changes to the visual system take place, such as anatomical changes of the eye that alter visual abilities and reduce the amount of light reaching the retina. Eye movements are affected by these physiological changes, resulting in the deterioration of distance and motion perception (Eby, 1998).

In 2007, a series of tests was developed for assessing the general health of elderly drivers, including the "Pelli-Robson Test", which measures contrast sensitivity and the "Snellen "E" Test" which measures visual acuity (Eby, 2007). It was observed that static visual acuity, which is necessary to perceive details, decreases with age. Aging also causes others changes in the eye such as the reduction of muscle tone, which affects focusing near objects. The sight improves with lighting (Holland, 2001), thus adjustment of road lighting conditions could facilitate visual perception.

Several researchers have shown that visual acuity is not correlated with accidents in older drivers (Holland, 2001; Wood, 2002). The reduction in contrast sensitivity may cause difficulty in the perception of signs (Ball, 1993). Dynamic visual acuity, is the ability to observe moving objects, and this too decreases with age (Ball & Sekuler, 1986; Burg, 1967).

Some eye diseases are typical of old age such as glaucoma and cataracts. Glaucoma is a disease that affects the optic nerve and can eventually lead to blindness. In the eye affected by glaucoma, the outflow of aqueous fluid is impeded, so the liquid accumulates increasing the intraocular pressure, compressing the optic nerve, Damage to the nerve fibres results in a progressive alteration of the visual field, which gradually shrinks until it disappears completely. When the optic nerve fibres are damaged, blind spots (scotomas) develop in the peripheral part of the visual field impairing vision.

Cataract is the clouding of the crystalline lens and leads to a progressive blurring of vision. The lens is necessary to focus images on the retina. The most common symptoms are blurred vision, halos and sensitivity to light and glare (such as headlights of an oncoming car). The opacity of the crystalline lens may increase the risk of glare; combined with poor road conditions this may make it difficult for older drivers to perceive road markings (Holland, 2001). Glare problems in the elderly are associated with poor street lighting, to the conditions of the road surface which can be minimized by proper road design (Staplin, Lococo and Byington, 1998).

A study by Owsley et al. (2001) showed that for the elderly suffering with cataracts, surgery has a positive impact on driving performance.

3.11.2.2. Hearing

The human auditory system allows us to perceive and localize sounds. A sound is a combination of waves released into the air from a source. The ear receives and translates the sounds into electrical impulses that are transmitted via the auditory nerve to the brain, where they are analysed and interpreted. Hearing impairment affects driving performance and the

risk of having an accident to a lesser extent than visual problems (Sims et al. 2000, 1998; Ivers et al. 1999).

For the purpose of analysing driving behaviour in drivers affected by hearing loss, 48 drivers were tested in driving situations with varying degrees of complexity. This study showed that hearing problems affect driving behaviour only in complex situations (Thorslund et al., 2013).

3.11.3 Physical function and medical conditions

The physical condition of a driver affects his aptitude to driving (Anstey et al. 2005). When a driver receives a stimulus, he must choose the proper response and perform the correct procedure in time, so as to achieve the intended effect.

With aging bone density decreases progressively in both sexes, but more quickly in women. This process causes an increase in bone fragility and thus the increased risk of fractures and may also be accompanied by diseases that impair the motor skills required to drive. Physical factors that can affect driving performance are: functional impairment, falls, orthostatic hypotension (Margolis et al., 2002), heart disease, arthritis (McGwin et al., 2000), grip strength (Sims et al.; 2000; 1998), rotation of the neck, shoulder rotation, trunk rotation, finger rigidity (Marotolli, 1998).

McGwin et al. conducted a study in 2000 that showed the correlation between accident risk and heart disease and strokes in women and also found arthritis to be a risk element.

In the studies examined, the most significant risk factors are: orthostatic hypotension (HR = 1.10 to 12.5 mm Hg), falls that occurred in the previous year (HR = 1.5) and the reaction time of the foot (HR = 1.10 to 0.06 seconds) (Margolis et al., 2002).

Marottoli et al. in 1998, found that the reduced rotation of the neck doubles the risk of an accident. This impairment causes difficulties for drivers at junctions, as the visual stimuli required to satisfactorily negotiate the situation are located at the extreme periphery of the visual field.

Research has also shown that no significant correlation exists between accident risk and physical factors such as invalidity, trunk or shoulder rotation and grip strength.

Drivers who have physical impairments are more aware of their limitations than those with cognitive deficits and are often more cautious or stop driving voluntarily.

In addition, the physical frailty of older drivers increases their likelihood of suffering physical damage compared to younger drivers (Evans, 1991; Massie & Campbell, 1993). For this reason, these drivers are over-represented in fatal and serious accidents (Hauer, 1988; Maycock, 1997).

3.12 Design strategies to assist older drivers

3.12.1 Strategies for road design

Empirical knowledge and the results of many studies have led to a number of principles and measures being formulated that are useful for all road users but particularly important for older drivers (Blonqvist, 2004). The infrastructure must be designed so as to ensure visibility of the roadway and evoke correct expectations and driving behaviour from road users. In addition, all elements of the road and the environment should interact so as to give a clear and unequivocal message to the driver; the level of the stimuli must be adapted to the processing ability of the drivers. The road elements should be sized so as to allow elderly drivers to perform all the required maneuvers within times compatible with their capabilities. Road signs should be positioned so as to allow drivers to read the information in time, process it, select an appropriate strategy and execute it.

3.12.2 Adapting vehicles to the functional limitations of the elderly

Vehicles should be properly adapted to the needs of older drivers and the difficulties they encounter, caused by the limitations described in the previous paragraphs.

Advanced driver assistance systems can compensate for the limitations of older drivers and help to reduce the risk of their being involved in accidents. These devices have various functions:

- draw attention when approaching other vehicles or at junctions;
- controlled driving speed;
- controlled braking (ABS and automatic handbrake)

The interface of advanced driver assistance systems must be properly designed in order to reduce driver distraction.

Other systems that generally reduce severity of injuries, such as airbags or seat belts may increase the severity of injuries in the elderly. To avoid this, the force of action of the device is limited and is adapted to their musculoskeletal features. Some examples are:

• Dual-stage airbags: to avoid abrupt contact;

• Active headrests: to minimize whiplash injuries to the neck;

• Side airbags: protect the head and chest in the event of a side collision. These are vital in accidents caused by left turns, one of the most dangerous manoeuvres for elderly drivers.

3.13 Licence renewal

The assessment of fitness to drive may be required for licence renewal or after serious injuries that can affect driving ability.

In the 27 European countries, different rules are in force for the renewal of driving licences, and different practices followed for testing driving skills (CONSOL - European Commission, 2013).

In some countries such as Finland, after the age of 45, drivers undergo a medical review every five years, covering general health status and vision. The renewal period for 70 year olds depends on the physician. In Italy a medical review for licence renewal is also required every five years after the age 50 and every three years for drivers aged 70 and over. In Germany, renewal does not depend on driver's age. Belgium and France do not require driving licences to be renewed. In the United Kingdom, a self-declaration of ability to meet vision standard is required, and any medical condition that could affect driving must be reported to the Licensing Agency.

In Denmark, a doctor's certificate is required every two years for drivers aged between 72 and 79, and every year for those aged 80 and over. In the Netherlands over 70 year-olds are required to renew their licences every 5 years but the frequency can be higher depending on their health status. In the latter case drivers undergo a medical examination and an eyesight test. So in Europe there are four types of licenses:

- "Licenses of unlimited validity - that means they are valid for the whole life. Unlimited licensed are issued by Austria, Belgium, Bulgaria, France, Germany, and Poland".
- "Licenses that generally do not require a medical examination to be renewed but only an administrative procedure (Sweden) and a self-report of medical conditions (UK)".
- "Licenses that require a medical check by (at least) a physician to be renewed with the age of first assessment at 50 (Italy, Portugal), 60 (Czech Republic, Luxembourg), 65 (Greece,

Slovakia) or 70 years (Cyprus, Denmark, Finland, Ireland, Malta, The Netherlands, Slovenia)".

- " Licenses that have to be renewed every ten years including a medical examination for all age groups (Romania), with increasing frequency with increasing age starting at 40 (Hungary), 55 (Lithuania), 60 (Latvia), 65 (Estonia, Spain)".

(CONSOL - European Commission, 2013).

The distribution of countries with the different type of licenses is shown in the following figure:

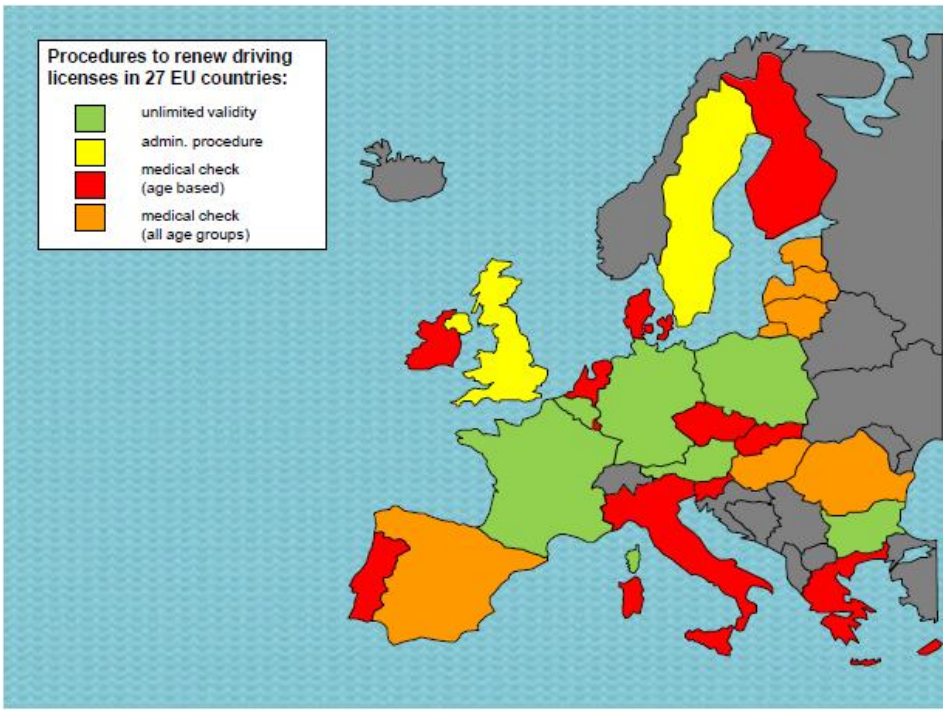

Figure 6 Types of driving licences in Europe – Source : (CONSOL - European Commission, 2013).

In one study procedures for licence renewal and accident rates in older drivers were compared in Sweden and Finland. In Sweden drivers are not required to renew their driving licence, while in Finland drivers over seventy have to undergo a medical before their licence can be renewed. Analysing accident rates, did not reveal any substantial difference in the number of accidents,. However, a higher rate of mortality was found among older road users in Finland, probably due to the 'increase in the number of elderly pedestrians who have lost their driving licence (Blomqvist, 1996).

The opportunity to modify driver licence legislation, covering the validity and renewal periods, was presented in Europe through the EU- directive 2006/126/EC (EU, 2006), but many countries did not revise their policies.

The European Driving Licence Directive entered into force in 2006, is aimed to influence road safety in two ways: by introducing questions focused on fitness to drive

during theory tests to achieve a licence; and by harmonising medical tests and minimum standards of physical and mental fitness required to obtain and renew licences (European Transport Safety Council, 2010).

There is no evidence that age-based controls have any safety benefit and result considerable costs, but these controls should be seen as a necessary investment, also to promote public health and disease prevention (CONSOL - European Commission, 2013).

3.14 Driving cessation

Many aspects of driving cessation have been studied in recent decades. The results of studies conducted in Europe and USA are similar. In North America, drivers stop driving at an older age than their peers in Europe, around 70 years old, and the consequences are more severe. This behaviour probably reflects the fact that Americans are more automobile-dependent.

A cross-sectional study involving 1950 elderly drivers in California, investigated the motivations that caused them to stop driving. Six reasons were identified. The main reasons were: health problems (41%), age-related changes (19.4%), problems with licence renewal (12.2%), "other" (12.1%). Some people stated they did not need a driving licence because someone else could drive for them (10.8%), and for others the problem was the cost of vehicle maintenance (4.3%). About 65% of these drivers, who had stopped driving in the past five years were female and had an average age of 85.5 years old.

It also showed that 2% of drivers stopped driving when they were 60, 18% when they were 70, 63% were 80 years old, and 17% were 90 years old. (Dellinger, et al, 2001).

A study conducted in 1993, involving 309 drivers investigated a number of factors associated with driving cessation. The most significant medical conditions were: Parkinson's disease, stroke, arthritis, hip fracture, eye problems, cataracts, glaucoma and depression (Marottoli et al., 1993).

A study conducted in the United Kingdom, which involved 108 elderly revealed other reasons in addition to the health conditions (28.6%), such as the loss of confidence in their own abilities or other psychological reasons (17.9%) (Brayne et al, 2000).

3.14.1. Gender differences in driving cessation

A study conducted by Siren in 2005 reported substantial differences in the behaviour of older men and women. After the age of 65, women tend increasingly less to renew their driving licence than their peers of the opposite gender. This is because women feel themselves unsafe and at risk of error, and for this reason they stop driving when they are still able to drive. Older men, instead can hardly admit that they are unable to perform an activity they have done for a long time and in which they have many years of experience, and considering the importance of driving to the male identity, driving cessation occurs only when their have severe health problems (Siren, 2005).

With the aim of investigating the reasons behind driving cessation in older women, an e-mail survey was sent to 2970 Finnish women. The driving history of women who had given up driving or renewed their licence at the age of 70 was compared. The duration and level of driving activity were strongly associated with the cessation or continuation of driving. Ex-drivers had an inactive personal history, while drivers had a personal history of more active driving. Especially women with an active role decided to stop driving for reasons similar to those known for older men. The results showed that the cessation of driving is related to driving habits and not to gender (Siren, 2005).

3.15 Assessment of fitness to drive

The fitness to drive of an older person can be assessed through a medical examination, upon licence renewal or when a particular health problem arises.

The medical examination does not provide an absolute evaluation of driving ability, because, it is not just one characteristic that reduces the ability to drive, but this will depend on the simultaneous decline of a series of mental and physical abilities. For this reason, the test performed for licence renewal should assess both cognitive skills and physical abilities.

In several studies different techniques have been used in order to evaluate fitness to drive, such as on-road testing (Carr, 2011; Justiss, 2005; Dobbs, 1998), driving simulator test (Vaux, 2010; Anderson, 2005), and batteries tests for evaluate mental and physical abilities (Stav, 2008; Eby, 2007).

In a study conducted in 1999 (McKnight, 1999), the correlation between physical deficits and driving performance in older drivers was evaluated. The survey involved 407

drivers over the age of 62, of which two-thirds were indicated by the agencies responsible for driving licence renewal for their high accident rate and the others were volunteers.

The abilities of the drivers tested were measured by means of a computer-based test called APT (Automated Psychophysical Test), which evaluates 22 skills including visual, attentional, perceptual and psychomotor skills.

Driving performance was measured by means of a road test, which included a series of specific tasks such as crossing junctions, driving along straight roads and roads with bends, changing lanes, merging into a traffic stream. Manoeuvres difficult for elderly drivers, such as judging the gap needed for crossing a traffic stream, selecting a direction from the information present in road signs and maintaining spatial orientation driving around a land mark were included in the test.

Psychophysical characteristics and driving performance were evaluated separately and the correlation with accident rate was determined. The test that measures physical and mental abilities may be more useful in identifying drivers with high accident risk, compared to road tests. In addition, the test is more accurate and quick to perform and can be used as a monitoring tool of age-related functional decline.

In 2007 (Eby et al) developed a battery of tests to evaluate the performance of drivers in old age, in order to identify any deterioration of driving performance and change in accident risk.

The tests included in the battery have been chosen according to their reliability for assessing cognitive and physical abilities and because they were inexpensive and quick to perform, so as to develop a useful and easy to manage tool.

The battery consists of 17 tests that are used to assess the following aspects: contrast sensitivity, visual acuity, balance, coordination, strength and reduction of body rigidity, shoulder flexibility, trunk flexibility, functionality of the central visual field, reaction time, strength in the hands, physical and mental wellbeing, depth perception, visuospatial abilities, test for hand coordination and manual dexterity, attention, concentration, executive function, cognitive function, driving behaviour and opinions regarding driving and demographic information.

To evaluate the battery of tests processed, a sample of 38 drivers over the age of 65 was analysed.

According to the results obtained in the survey, the assessment battery was found to be efficient for the assessment of physical and mental status and driving behaviour. These

tests are also cheap, easily transportable, and easy to use for drivers and for examiners, even without medical training.

Stav et al. conducted tests (2008) with the aim to identify a series of tests easy to manage for driving examiners in the evaluation.

The test sample included 123 drivers over the age of 65 possessing a valid driving licence. The tests were chosen from a range of tests, considered predictive for risk assessment and administered to participants in the Older Driver Consensus Conference (2003). The drivers tested underwent clinical tests to assess their cognitive, visual, motor skills and they also completed a test to assess their knowledge of traffic rules. The drivers were also tested on a standard 15 mile driving route of. A score from 0 to 3, called the Global Rating Scale, was assigned to each driver as follows:

0 Driver unsafe (irreversible).
1 Driver unsafe (but reversible);
2 Driver not dangerous but with restrictions and recommendations;
3 Driver not dangerous in any driving situation.

In order to identify the test or battery of clinical tests that are more predictive of driving ability, a linear regression analysis was conducted and the best model ($R = 0.665$, $R2 = 0.443$) was included. The results of the of contrast sensitivity test, Rapid Pace Walk Test (physical test for the assessment of motor speed, coordination and balance), assessment of the visual field and the MMSE score (cognitive test) explain 44% of the observed variability, in the Global Rating Scale, for assessing driving performance and include the assessment of visual acuity, cognitive and motor skills. It is important to highlight that driving is a complex task that requires the simultaneous use of different cognitive, visual and motor functions. For this reason it is necessary to evaluate simultaneously the efficiency of different functions.

Risser (2008) assessed the validity of two computer-based batteries of tests developed by the Expert System Traffic, standardized using road tests. Through these tests, the performance of the drivers was assessed and they were divided into unsafe or safe drivers.

Two versions of the test battery Expert System Traffic (Sommers, 2005) exist: Standard and Plus. These evaluate some cognitive abilities such as: level of intelligence, concentration, stress tolerance and response time, the Plus version also measures visual field and divided attention.

The validity of the test battery has been tested with neural network techniques and the results indicate that the test batteries are predictive of fitness to drive.

In 1993, a driving test was developed for testing the driving performance of people who had suffered a traumatic brain injury (n = 35) (Thomas Galski, Bruno, and Ehle, 1992). Drivers are subjected to clinical trials to evaluate the cognitive and executive functions. Through an index related to performance on the road, fitness to drive is assessed and through another index familiarity with the vehicle controls was evaluated. The tests were evaluated using the dichotomous score 1 if the test was passed and 0 if the test was failed.

The cognitive measures explained 64% of the variability of the score in the test drive. Also taking into account the assessment of familiarity with the vehicle controls the variance explained was 93% (T. Galski, Bruno, and Ehle, 1993).

A study conducted by Justiss (2005) was divided into three different experiments, in order to develop a method for assessing driving performance.

During the experiment 95 drivers were tested between the ages of 65 and 89 years. Driving tests were carried out on a 15 mile route of a mean duration of 51.9 minutes (SD = 7.4). Along the route the drivers had to perform 91 maneuvers, such as left and right turns, changing lane, merging into traffic and the ability to maintain position in the lane and speed control were also evaluated. Their driving ability was judged according to the "Global Rating Score". Two examiners were present in the vehicle during the test. They judged the execution of each maneuver, with a score from 0 to 3, assigning 3 if no error was observed, 2 if one or more errors were observed, 1 if one or more errors requiring verbal warning to change driving behaviour were observed and 0 if one or more errors were observed which required physical action on the part of the examiner or violations of traffic rules.

Their cognitive abilities were measured by the Mini Mental Status Exam, their visual field was measured by the UFVO test and their level of independence in daily activities by Functional Independence Measure (FIM) and OARS tests. Other elements were measured regarding the health status such as the level of pain with Jette pain Scale, the level of depression with the Geriatric Depression Scale (GDS) and the number of medications taken. It was found that the BTW (behind the wheel) is an effective method to measure driving performance.

The generalizability of the test in different contexts and different geographic locations has been studied testing 42 drivers. It was found that there was no significant difference between

the scores obtained in the two different paths, but the tests must be performed during daytime and with a southern climate with minimal rain.

In a study conducted in 2012, the influence of cognitive skills in driving ability was assessed by comparing the results obtained in the MMSE (Mini-Mental State Exam) and the standard road test. The MMSE is a test consisting of 11 questions, and it is divided into two parts. This test is used to measure the orientation, the level of attention and memory, and the ability to execute the instructions provided by the examiner. Driving performance was evaluated by a well-known standard test for assessing driving performance in the elderly, proposed by Justiss in 2005. 168 elderly drivers were tested, twenty of them had Parkinson's disease. The drivers were all aged over 65 years and all had their driving licence. The results of this study show that the MMSE is not a complete tool for evaluating driving performance and must therefore not be used as the only test for the assessment of these skills (Crizzle et al, 2012).

The absence of illness does not mean to be fit to drive (European Transport Safety Council, 2010), and also recent studies in traffic psychology showed that adequate psychophysical skills and mental functions are not sufficient for safe driving, and they highlight the importance of motivational and attitudinal factors in the fitness to drive (Peraaho, 2003, Rothengatter, 1997).

Hierarchical approaches have been used in several studies, when trying to conceptualise and explain human behaviour in traffic psychology (Janssen, 1979; Ranney, 1994), but this approach can be used to combine the motivational and attitudinal aspects of driving behaviour with performance or operations in certain traffic situations (Peraaho, 2003).

From hierarchical approaches derive the “Goals for Driver Education – framework”, proposed by Hatakka in 2002. The study has been acknowledged within the European traffic research community, because it gives the guidelines when developing traffic educations for novice drivers (Peraaho, 2003), and it can also be used during trainings for older people, that can prolong their driving activity (CONSOL - European Commission, 2013).

4. DEVELOPMENT OF A TOOL TO ASSESS DRIVING ABILITY

4.1. Work Ability Index

The Work Ability Index is a widely used tool in the field of occupational medicine and since its introduction has been translated into 24 languages. This indicator was proposed in 1998 by Ilmarinen and Tuomi, with the aim of assessing the ability to work and predict its evolution in the short and in the long run. It also aims to highlight the aspects that can affect the working ability of an individual.

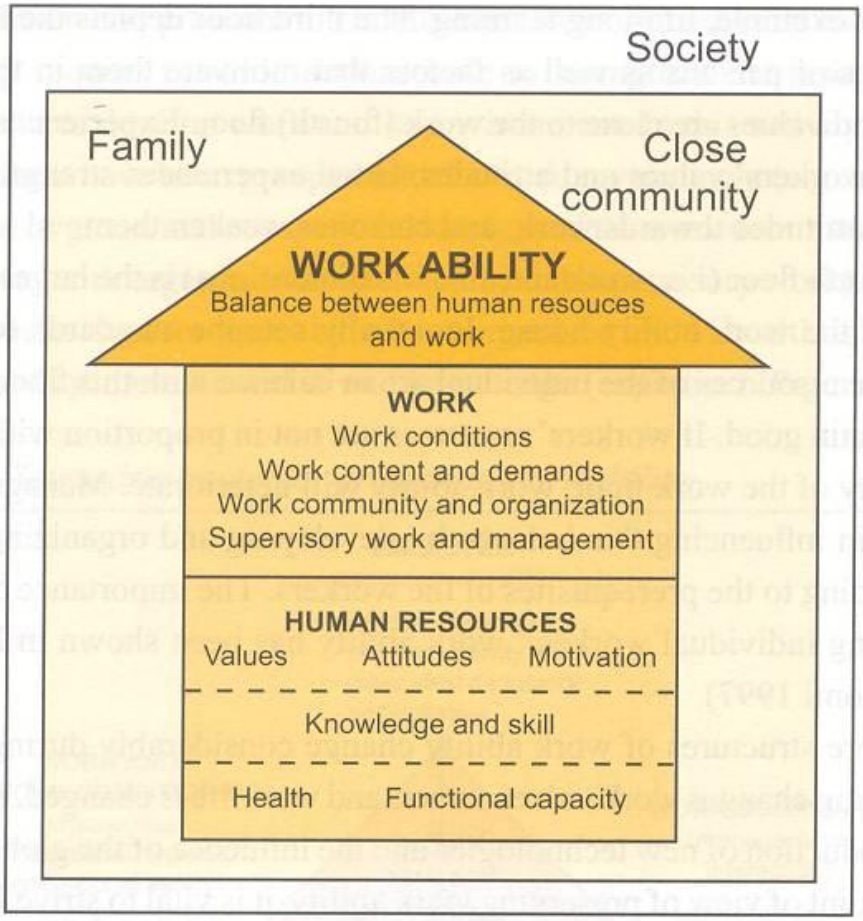

Figure 7 Role of working ability – Source: Illmarinen, 2006

The Work Ability Index is calculated on the basis of replies to a questionnaire structured into 7 sections, constructed so as to analyse the following aspects:

1. Current working ability compared with the best time of life (based on the answers the score can be from 0 to 10);

2. working ability according to the needs of the task (based on the answers the score can vary from 2 to 10);

3. Number of current medical diagnoses, this section includes a list of 51 diseases and health problems, according to the responses score can range from 1 to 7, and it is calculated as follows:

At least 5 diseases = 1 pt.

4 diseases = 2 pts.

3 diseases = 3 pts.

2 diseases = 4 pts.

1 disease = 5 pts.

0 disease = 7 pts.

4. reduction of work capacity due to illness estimated by the individual (according to the responses the score can range from 1 to 6);

5. temporary cessation from work because of illness in the last 12 months (according to the responses the score can range from 1 to 5);

6. personal assessment of work capacity for the next two years (according to the responses the score can be 1-4 - 7);

7. Conditions / psychological resources (according to the responses the score can range from 1 to 5).

Each section contains a number of questions and a score is assigned according to the response. The weighted sum of the scores totalized in each section represents the Work Ability Index and its value can range from 7 to 49. On the basis of the score it is possible to identify the level of working ability. The levels of work ability are:

- poor work ability: 7-27 points;
- moderate work ability: 28-36 points;
- good work ability: 37-43 points;
- excellent work ability: 44-49 points.

The score levels chosen for identifying the four levels, ie 27, 36 and 43 points correspond respectively to 15 °, 50 ° and 85 ° percentile of the distribution of the scores. For each level of work ability there are several objectives to achieve and they are shown in the following figure.

Score	Work ability	Goals
7-27	Poor	Restore work ability
28-36	Moderate	Improve work ability
37-43	Good	Support work ability
44-49	Excellent	Maintain work ability

Figure 8 Objectives for each work ability level

4.2.Adaptation of the Work Ability Index for calculating Driving Ability Index

Driving like work is a task that requires the use of physical and mental resources and driving is also a job in numerous sectors, so it was decided to adapt the questionnaire Work Ability Index, in order to understand the changes that occur with aging and that may affect the ability to drive.

This phase of the research has been conducted with the Medical Section of the Centralabs (Centre of Competence for Transport in Sardinia), of Cagliari, under the supervision of Professor Michele Meloni (Occupational Medical) and with the collaboration of Professor Giovanni Costa, Department of Clinical Sciences and of the Community, of Milan Polytechnic, who was responsible for the adaptation of the Work Ability Index in Italian. Like the Work Ability Index (WAI), the Driving Ability Index (DAI) was calculated on the basis of responses to a series of questions in a questionnaire. The questionnaire was appropriately redrafted so as to adapt it to the evaluation of the ability to drive in general and specifically to identify the changes that occur in old age and the typical diseases of old age.

The questionnaire consists of the following sections:

1. Current driving ability compared with the best time of life;
2. Driving ability in relation to the requests of the task;
3. Number of current diseases diagnosed by a doctor;
4. Reduction in driving ability due to disease estimated by the individual;
5. Temporary driving cessation for diseases in the last 12 months;
6. Personal prediction of ability to drive for the next two years;
7. Driving activity.

Specifically, all the questions relating to working activities have been modified in order to analyse the same issues in a driving context.

The first part of the questionnaire contains questions about demographic information, general information about the driver and general information about driving. These questions in the first draft of the Driving Ability Index questionnaire, as in the Work Ability Index are not considered for calculating the score. This first part investigates aspects such as age, fundamental to the study, marital status which is very important especially in women, who, if married, rarely use the car as driver but only as passenger because usually it is the husband who drives. As mentioned in previous chapters, for this reason women tend less to renew their driving licence in old age than their peers of the opposite gender. The gender of the driver is of fundamental importance. As was found in a study conducted by Blonqvist in 2003, women give up driving the car when it is no longer necessary for them to carry out functions related to the family, such as taking the children to school. Instead men drive to be independent. In addition, women tend to stop driving car when they are still able to do so whereas men typically overestimate their abilities, because they often do not want to admit that they are no longer able to perform an activity they have done for a long time. More questions are about education and work that influences health. Other questions are about smoking, consumption of coffee, alcohol and psychoactive substances and level of satisfaction with the quality of sleep.

Driving information concerns: the type of licence obtained and year, drivers were also asked whether they had ever let their licence expire and how long had passed before renewal, the type of vehicle and year of manufacture. This information particularly affects the level of injuries in accidents involving elderly drivers, because new vehicles are easier to check for the presence of devices such as power steering, or automatic gears and they are built according to the criteria required to dissipate the impact energy on the vehicle and not on people on board.

In this section, information about smoking and cell phone usage while driving are required, because they could distract the driver.

Section 3 of the Work Ability Index has been changed, in addition to the diseases listed some diseases that are particularly disabling for driving were included such as obstructive sleep apnoea syndrome and others that are typical of old age such as cataracts and glaucoma.

The main change in the questionnaire is the introduction of section 7 concerning the task of driving and that has been designed to investigate driving habits, such as frequency of car use, that has a direct correlation with driving performance. As is known from human factor studies, practice improves the general level of performance and ensures a slower

decline of attention during the task. Questions also include the frequency of seat belt use, as this only became compulsory in 2006 in Italy. Consequently most older drivers have driven for years without and wearing a seat belt is not a normal and almost automatic habit as it is for drivers who instead have recently obtained their driving licence. In this section the frequency of use of the rear view mirror is also evaluated, as it is indicative of a more careful driving style.

This section includes questions regarding driving behaviour, such as the number of offences committed, the time elapsed since the offence, any involvement in accidents and the nature of the damage. Drivers are also asked whether they have ever fallen asleep at the wheel, an indication of the level of general well-being.

Other questions are related to the use of medications that can impair their ability to drive.

In the final part of this section questions related to driving difficulty are included, such as difficulty in perceiving traffic signs or other difficulties when driving at night.

Night time driving becomes difficult for elderly drivers, due to the slower adaptation of the eye to changes in the brightness level. In this section drivers are asked if they are stressed by driving or when merging into traffic in low light conditions, if they have particular difficulty in perceiving road markings or the guard rail, if they need to reduce their speed in order to perceive signs when driving at night or if they feel that the road is poorly lit.

Based on the responses to the questionnaire it is possible to calculate the score that corresponds to a level of driving ability. For each level a different goal must be achieved.

Score	Driving ability	Goals
7-27	Poor	Restore driving ability
28-36	Moderate	Improve driving ability
37-43	Good	Support driving ability
44-49	Excellent	Maintain driving ability

Figure 9 Objectives for each driving ability level

4.3. Pilot survey

During the first phase of drafting and adaptation of the questionnaire, a pilot survey was conducted in Cagliari (Italy), which allowed to refine the questionnaire in some parts. The interviews were conducted by Claudia Pinna, Dr. Luigi Lecca and Professor Michele Meloni, who instructed us how to obtain all the information and in particular with regard to Section 3, relating to health conditions.

This survey involved 54 elderly drivers, 16 women and 38 men, because women renew their licence less than men in old age (Siren et al., 2005). They were in possession of a regular driving licence, and drove regularly at the time of the survey. Drivers have been randomly selected to be representative of the whole population.

4.3.1. Frequency Analysis

The drivers interviewed were aged between 65 and 84 years old, the average age of the sample was 70.5 years. The average age of the women interviewed was 71.3, ranging from 65 to 78 years old, the average age in the sub-sample of men was 70.1, ranging from 65 to 84 years.

The majority of drivers tested were married (70.4%), 12 were widowed (22.2%), two divorced (3.7%) and one of them was widower and one was single.

As for education that 27.8% had only attended primary school (15 drivers), the same number had a high school education , 13 drivers had completed middle school (24.1%) and 20.4% had obtained a university degree (11 drivers).

81.5% of drivers were retired, the remaining 10 drivers were still working at the time of the survey.

48.1% of drivers were ex-smokers, 37% had never smoked and 14.8% (8 individuals) were smokers at the time of the survey. The question concerning the consumption of alcohol showed that 77.8% of the sample usually drank wine and beer, 11 never consumed alcohol (20.4%), and only one driver frequently drank wine, beer and spirits.

The great majority of drivers drank between one and three cups of coffee a day (77.8%), 8 drivers did not drink coffee and 4 drank more than 3 a day.

None of the drivers included in the pilot study had ever taken psychoactive substances, so this question was omitted from the questionnaire, as better specified in the following paragraphs.

Of the drivers tested 68.5% said they were satisfied with the quality of sleep. This information is relevant for older drivers, because often with age the quality of sleep is altered as a result of changes in hormone levels, blood pressure, body temperature, and alterations in circadian rhythms. These changes often result in early morning and frequent night-time awakenings. Poor sleep quality is often compensated with frequent short-term numbness during the day (Klein, 1997).

All drivers tested had a type B licence to drive just cars. Drivers who had obtained a type B licence before April 26, 1988, could also drive some types of motorcycles, though nowadays this requires a type A licence. Of the drivers interviewed, the most recent licence dated to 1988, so all the drivers also had the chance to drive motorcycles.

In addition, during their lifetime 5 drivers had obtained other types of licences to drive heavy vehicles: 3 possessed a type C licence for driving lorries or vehicles used to transport goods, one had a type D licence for driving vehicles for passenger transport and 1 had a type E licence, an extension of licences B, C, and D for towing heavy trailers.

The participants had been driving on a regular basis on average for 47.1 years, ranging from a minimum of 26 to a maximum of 67 years. 92.6% of the drivers had never let their driving licence expire while four had let their licence expire for a short period (one for 1-2 months and one who had been suspended for a driving offence for a period of 6 months).

Most of the users drove subcompact cars (63%), 14 (25.9%) regularly used a saloon car, two of them drove off-road vehicles, two a station wagon, one a small van and one a sports car.

3 drivers (5.6% of the sample) admitted using a mobile phone while driving. Of the 8 smokers in the sample 50% smoked while driving, a high risk factor, especially when driving at night.

Self-assessment of ability to work compared to the best period of one's life is one of the key elements of the Work Ability Index, indeed the question to which the highest score is assigned. Similarly, in the Driving Ability Index drivers were asked to rate their driving ability with a score ranging from 0 to 10. Thirteen drivers (24.1%) gave themselves a score of 10, five a score of 9 whereas the majority of drivers (35.2%) answered 8; ten respondents rated their driving ability as 7, four rated their skills sufficient, equal to 6, and three judged their skills to be inadequate, with a rating of 5.

The self-assessment of driving skills continues with the next questions, in which drivers are asked to assess their physical, mental and cognitive abilities in relation to driving.

55.6% of drivers (30) stated their physical abilities were good enough for driving, nineteen drivers felt their physical abilities were very good, whereas only five (9.3 %) judged their physical fitness as average. None of the respondents rated their physical abilities as fairly poor or very poor.

However, with respect to cognitive skills, 57.4% of drivers had sufficiently good abilities, 33.3% (18 drivers) very good and five average cognitive skills. Again none of the respondents rated their skills as fairly poor or very poor.

The section about diseases is divided into various parts subdivided by type; the categories indicated are: diseases caused by accidents, muscular-skeletal complaints, cardiovascular diseases, respiratory disorders, mental, sensory and nervous disorders, digestive disorders, genitourinary disorders, skin complaints, tumours, endocrine and metabolic disorders, blood disorders and other illnesses / disorders.

Twelve of the drivers tested had problems caused by accidents, nine of them reported a disease and three had two problems. Musculoskeletal diseases had been diagnosed in thirty-two drivers, more than half of the sample (59.26%), most of them (46.88%) only had one disease, nine had two such diseases, six had three musculoskeletal disorders, and two drivers had four of these diseases. Twenty-three drivers had cardiovascular disease, fourteen of them only had one disease, four had two diseases, and five had a single disease in this category. The most frequent pathology was hypertension.

Nine drivers, had diseases of the respiratory tract, of whom 6 had only one disease, two had two problems and one had three problems of this type.

Mental and sensory nervous disease were found in 29 drivers; of whom 72.4% (21 drivers) only had one disease, 7 had two diseases and one had three diseases of this type. Digestive problems were detected in 22 drivers (40.7%), of whom 16 have only one disease, four have two diseases, one three diseases and one has four diseases in this category.

Only five drivers (9.3% of the sample) reported some kind of skin problem and they each had only one disease of this type.

7.4% of respondents had benign or malignant tumours. 27.8% had endocrine or metabolic disorders, and all had only one disease of this type. One driver in the sample had a blood disorder and one had a deficit at birth. Neither had other illnesses.

On the basis of this information the total number of diseases reported by each respondent was calculated. The maximum number of diseases is observed in driver 16, and only four drivers (7.4% of the sample) did not have any disease at all.

In the following question, the fourth item, drivers were asked to estimate the reduction of their driving skills on the basis of health problems. 87% of drivers (47) said they did not have any trouble, four drivers considered themselves able to drive but had some difficulties, two said they were sometimes forced to slow down or change the way they drove and one felt able to drive only for short distances.

Item 5 concerns giving up driving for health reasons over the past year, specifically drivers were asked how long they had stopped driving because of illness, treatment, medical examinations or diagnostic tests. 74.1% of drivers (40) had never stopped driving for health reasons, 11% of them (6 drivers) had been unable to drive for less than 10 days, four drivers for a period ranging from 10 to 24 days, three drivers for a period ranging from 25 to 99 days and only one stopped for a period ranging from 100 to 365 days.

In item 6 drivers were asked to imagine how they would evaluate their driving ability in the two years following the interview. 90.7% (49 drivers) were fairly confident while five said they were not sure they would be able to continue driving two years on. Item 7 is a section of the questionnaire related to the driving task and includes a series of questions. 88.9% of drivers said they drive the car daily or at least 3 or 5 days a week, five drivers (9.3%) use the car every week (ie once or twice a week) and one uses the car monthly.

Drivers were asked whether they had ever committed a driving offence and how much time had elapsed since the last offence. 16 drivers (29.6%) had never committed an offence, thirty-five drivers (64.8%) had committed an offence more than a year ago, while three drivers had committed an offence in the last year. Only twenty-two drivers stated the reason for the offence, the most common being a parking offence (88.2% of cases), seven drivers were fined for speeding, two for crossing a red light and once drivers committed the following offences: "no entry", "failure to indicate", "no seat belt" , "driving with licence expired " and "parking ticket expired".

85.2% of drivers surveyed had never been involved in an accident, one was involved in an accident that caused property damage, and seven (13%) were involved in accidents that damaged property and people.

The majority of drivers (85.2%) always wore their seat belt; three drivers often used it, two drivers occasionally and three never wore their seat belt under any circumstances.

None of the drivers took medicine that affected their ability to drive. 96.3% of drivers had never fallen asleep at the wheel while two had (3.7%). Nearly all drivers (98.1%) stated they always used the rear-view mirror, only one said he used it often. 68.5% of drivers said they never saw road signs at the last minute, seventeen (31.5%) admitted they often saw road signs at the last minute.

With regard to the question "Have you given up driving at night because you are worried about merging into traffic," 38 drivers (70.4%) responded never, 10 (18.5%) responded often and 6 drivers (11.1%) never drove at night.

43 drivers were not nervous about traffic at night, 11.1% were often nervous drivers in this circumstance and 5 (9.3%) were always nervous driving at night.

To the question "When driving at night have you often found that the road is not sufficiently lit?" 20 drivers (37%) responded never, most of them (51.9%) responded often, and 6 drivers answered always.

41 drivers (75.9%) had no difficulty in perceiving road markings or the guardrail, nine of them (16.7%) often had some difficulty.

Half of the drivers tested were always forced to slow down at night to read street or road signs, 20 (37%) reported often having difficulties in this situation, seven (13%) always had difficulties.

4.3.2. Calculation of Drive Ability Index score in the pilot study

Average DAI for the whole sample is 39.8, corresponding to a "good" ability to drive. Men scored higher (40.6) than women (37.9), the difference probably being attributed to the slightly higher average age of the women in the sample

Analysing the scores obtained for different items in the two sub-samples grouped by gender shows that men have a higher score in Sections 2 and 6, calculated on the basis of self - assessment of ability to drive at present and in the near future (next two years). Also Section 7 showed that men have less difficulty in managing situations that occur at the wheel. than women.

Of the drivers involved in the survey, the driving ability of twelve drivers comprised of 4 women and 8 men aged between 65 and 75 was "excellent" (22% of the sample). No drivers aged over 75 were included in this group.

The driving ability of most drivers (54%) is "good". This group includes 24 men and 5 women. The ability to drive is "moderate" in 20% of the drivers interviewed, corresponding to reduced fitness to drive.

Only in 4% of the sample is the ability to drive "poor". This group includes only drivers aged over 75, suggesting that they should not be considered fit to drive. Thr effect of age on the DAI score for men and women was evaluated using linear regression techniques. Only for females is age statistically significant (t = - 4.436).

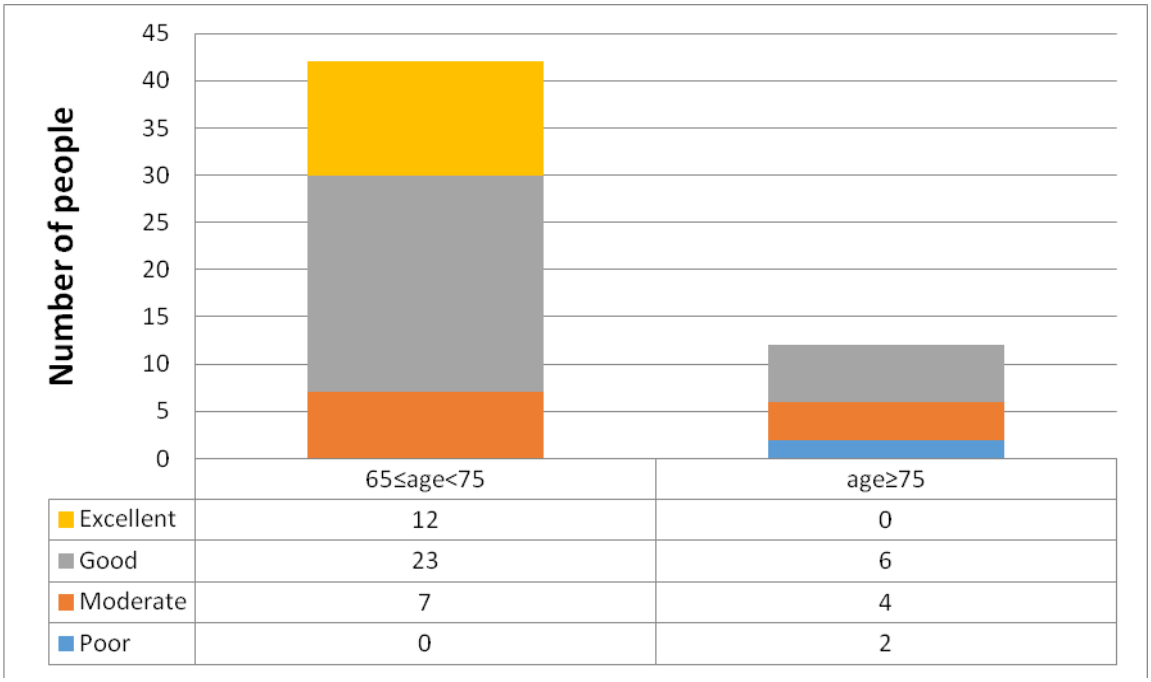

Figure 10 Number of drivers in each Driving Ability category.

Table 4 Mean age, mean DAI scores, gender and mean values of different items

		Age	DAI	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7
Sample	$\bar{x}$	70.5	39.8	8.2	8.4	2.8	4.8	4.5	6.7	4.5
54	(range)	(65-84)	(25-49)	(5-10)	(6-10)	(1 - 7)	(1 -5)	(1 -5)	(4 -7)	(3 -5)
Females 16	$\bar{x}$	71.3	37.9	7.7	8.2	2.9	4.6	4.0	6.4	4.2
	(range)	(65 -78)	(25 - 45)	(5-10)	(6-10)	(1 - 7)	(3 -5)	(1 - 5)	(4 -7)	(3 -5)
Males 38	$\bar{x}$	70.1	40.6	8.4	8.5	2.7	4.9	4.7	6.8	4.7
	(range)	(65-84)	(25-49)	(5-10)	(6-10)	(1 - 7)	(1 -5)	(1 -5)	(4 -7)	(3 -5)

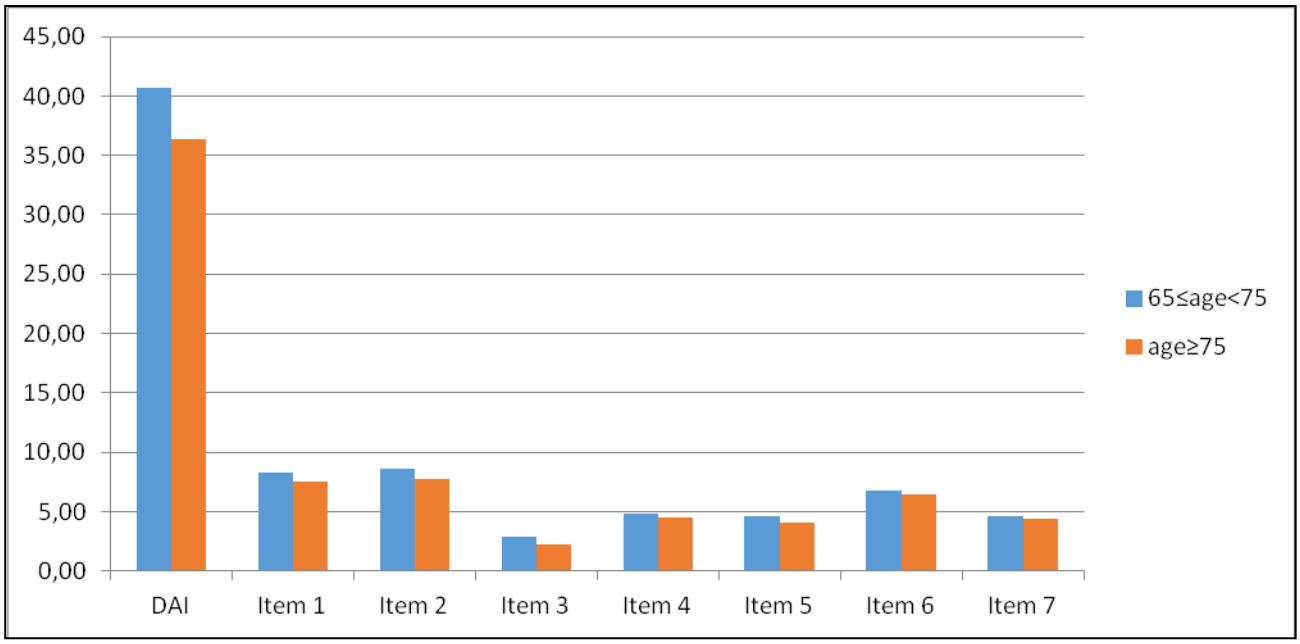

Figure 11 Average Driving Ability Index scores and score for each Item for different age groups.

Table 5 Mean DAI scores and mean values for different items by gender and age

	Gender		DAI	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7
	Females	Males								
65≤age<75	12	31	40.7	8.3	8.6	2.9	4.8	4.6	6.8	4.6
	28%	72%	(25-49)	(5 - 10)	(6-10)	(1 - 7)	(1 -5)	(2 -5)	(4 -7)	(3 -5)
age≥75	4	7	36.4	7.5	7.7	2.2	4.5	4.1	6.5	4.4
	36%	64%	(25 - 43)	(5 - 9)	(6-10)	(1 -5)	(3 -5)	(1 -5)	(4 -7)	(3 -5)

Table 6 DAI score groups and percentage distribution by gender and age

	Sample	Females		Males	
		65≤age<75	age≥75	65≤age<75	age≥75
Poor	2	0	1	0	1
	4%	0%	6%	0	2.6%
Moderate	11	4	2	3	2
	20%	25%	13%	7.9%	5.3%
Good	29	4	1	19	5
	54%	25%	6%	50.0%	13.2%
Excellent	12	4	0	8	0
	22%	25%	0%	21.1%	0.0%

Table 7 Description models

		Gender		Constant
Subsample	**R^2**	**Beta**	**t-test**	**t-test**
Females	**0.584**	**-0.764**	**-4.436**	**6.724**
Males	**0.022**	**-0.149**	**-0.919**	**5.003**

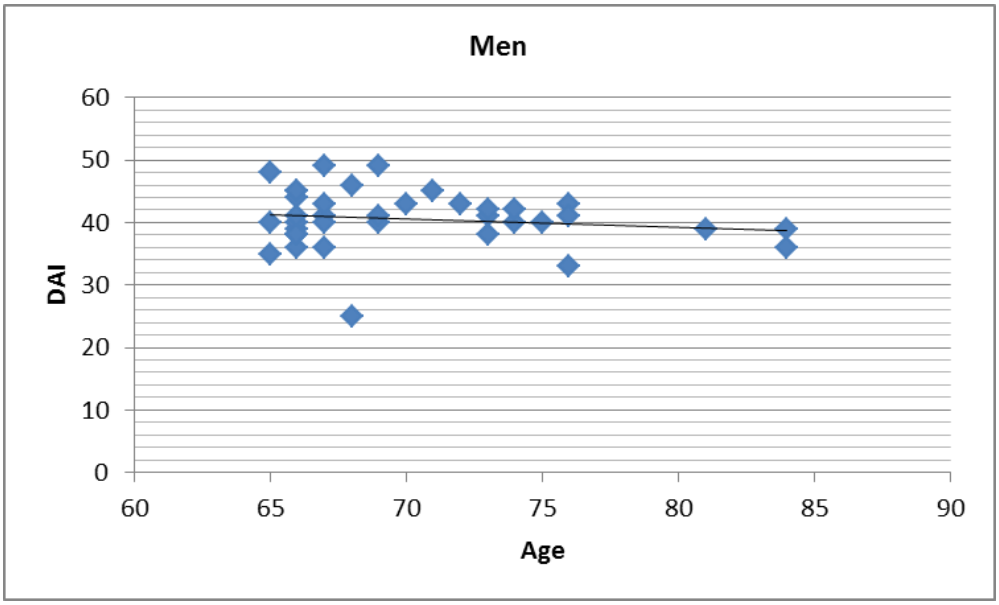

Figure 12 – DAI score and age for males.

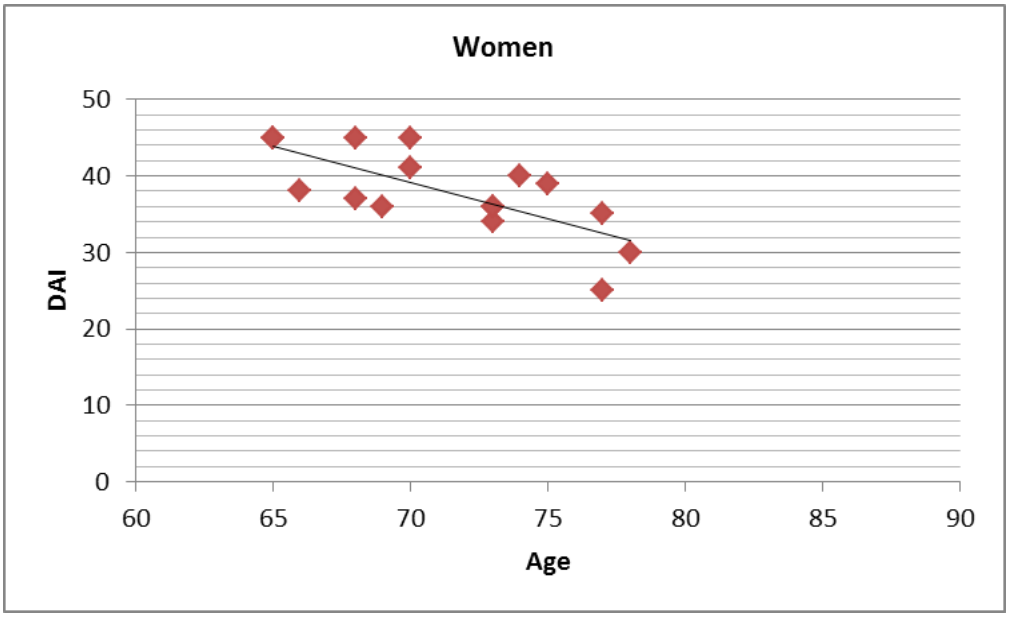

Figure 13 – DAI score and age for females.

5. EXPERIMENT 1: ON-ROAD EXPERIMENTS

5.1. Research activities in Newcastle upon Tyne

The following part of the research was conducted in collaboration with Dr. Amy Guo at Newcastle University in the UK.

In this phase, the questionnaire was translated into English, and modified on the basis of the results of the pilot survey. It was also adapted so as to avoid mistrust and maximize the level of compliance in British drivers.

To assess the validity of the questionnaire to predict the ability to drive, the tests were performed either on the university's driving simulator, or in on-road experiments.

5.2. Adaptation of Driving Ability Index to British culture

The first version of the Driving Ability Index questionnaire was modified according to the results of the pilot survey and some of the answers that were open-ended responses have become closed answers. Some changes were made in order to obtain the same information and maximize the level of response from the British drivers.
The question concerning education, has been adapted to the English system (no qualifications, GCSE / O-level and equivalents, A levels and equivalents, University degrees).

The question about alcohol use in the first draft was, "Do you drink alcohol?". This has been replaced with two questions, the first relating to the frequency of alcohol use, "How often do you have a drink containing alcohol?" the second to the amount of alcohol consumed "How many units of alcohol do you drink on a typical day? " in which the answers are expressed in units).

In a study conducted by Lisa Blonqvist in 2004 it was found that the accident risk of older drivers is overstated, because older drivers, compared with other age groups that travel the same annual mileage on average have the same probability of being involved in an accident.
According to this study two questions related to the daily and annual mileage have been introduced.

Drivers were asked what percentage of mileage driven annually is urban or rural (the sum of the two percentages is not necessarily 100%).

The question on marital status was very personal, so it was replaced with two questions which still investigate the same area. The first question asked if the participant drives mainly on his own or with other people, and the second question instead aims to know if participants when travelling by car are most often drivers or passengers. The question on the number of licences held was hard to manage because the categories of licences have changed several times over the years. This question has been replaced with the questions "Have you ever driven the following vehicles?" (Possible answers are Motorbike/ Van / mobile home / minibus/ Ambulance / Fire Engine, Sports car, Lorry / bus / Coach) and with a question relating to driving qualifications "Do you have any driving qualifications other than the standard DSA driving test?".

Questions about smoking whilst driving or drinking coffee were excluded from the questionnaire because in the pilot survey they did not appear to be of particular importance. Questions about the use of psychoactive substances and use of the phone while driving were also excluded because these activities are against the law and no one would actually give a truthful answer.

In the final section relating to the driving task " Have you given up driving at night because you are worried about merging into traffic?" has been removed as it was covered by the questions: "have you given up driving at night?" and "Do you worry about merging into traffic?".

This section has also been modified. The questions concerning the use of mirrors :- in the first draft the possible answers were always, often or never, and all the drivers involved in the pilot survey stated that they always use the mirror. In the second version the possible answers are: never, only before making particular manoeuvres and every few minutes.

5.3. On-road experiments

5.2.1. Validation of the questionnaire through on-road experiments

To evaluate the driving ability in the elderly, the test adopted by Justiss in 2005 and approved by the Elderly drivers Consensus Conference has been used. This test is mentioned

in previous chapters, and involves performing some special manoeuvres and crossing junctions, which are considerably complex for elderly drivers.

This specific on-road test has been chosen in order to evaluate driving performance, for its generalizability, because it can be applied in different contexts and different geographic locations, but under certain conditions (during daytime and with minimal rain), and because it allows to evaluate driving performance in four categories (Justiss, 2005) such as the Driving Ability Index.

5.2.2. Trial Description

The same instrumented vehicle was used for the on-road experiments. The vast majority of participants were used to a vehicle with automatic transmission or at least were familiar with it. The experiment was started by asking the participant to get into the vehicle to find his/her most comfortable position including finding the right height and back-support of the seat and the angle of the mirrors. Then they were offered the opportunity to drive the vehicle until they felt comfortable with it. This practice took place inside a big park indicated on the map below, owned by Metrocentre, a shopping complex located in Gateshead, a city near to Newcastle upon Tyne. This park was the start and end points of the experiment. The trial route is shown in Figure #. The participant was asked to complete the Driving Ability Index questionnaire upon completing the driving.

Figure 14 Location of Metrocentre car park – Source: metrocentre

5.2.3. The trial route

The tests took place on a 5.8 mile (9.33 kilometres) long circular route where there is a speed limit of 40 miles per hour at the beginning and end of the route, close to the Metrocentre shopping complex and of 30 miles per hour in residential areas (Dunston and Whickham). Estimated driving time in compliance with these speed limits was 18 minutes. The route is shown in the following map.

Figure 15 Test route– Source: googlemaps

As in the studies of Justiss in 2005 and Stav in 2008, the route used here includes signalized junctions with left and right turns, which prove very complex for older drivers (similar to left turns in countries with right-hand drive). There are several roundabouts of varying difficulty, a T-junction and many zebra crossings. There is also a 4-way interchange in which drivers are obliged to turn right. During the test drivers have to change lanes and drive through two tunnels, in one of which a lorry and other vehicles cannot pass at the same time.

Part of the test took place in a residential area where the speed limit is 30 miles per hour, while the remainder is on non-urban roads where the speed limit is 40 miles per hour.

In order to measure driving ability in older people, the ability to execute manoeuvres and cross junctions was evaluated.

Along the route, the drivers had to leave the car park and turn right at the 4-way interchange (Figure 14). Then they had to turn left at the traffic lights (Figure 15) and drive

through a tunnel. Next they had to turn left at a three way mini roundabout (Figure 16). then drive through a tunnel, in which a car and a large vehicle cannot pass together. At this point the route leads into the urban area.

At a zebra crossing it was checked if drivers paid attention to pedestrians. Drivers approached the multiple lanes. They crossed the traffic lights in Figures 17 and 18.

After they went straight on the left at the traffic light (figure 19), in a three arms junction.

They turned on the right in a T junction (figure 20), and after they went straight at the traffic light in figure 21 and in the figure 22.

There was a quite busy zebra crossing. They followed the route and they went straight on the right at the traffic light, in a three arms junction (figure 23).

They changed lane (figure 24) before they turned on the right at the traffic, in the three arms junction showed in figure 25.

They went straight at the two traffic light for pedestrians (figure 26), and they went straight at the roundabout (four arms) in figure 27. At this point the residential area finishes.

They crossed a tunnel and after they turned on the right in a uncontrolled junction (figure 28), where there is the buss lane on the left that confuse the drivers.

They changed lane (figure 29) and they turned on the right at the traffic light, in the four arms junction in the figure 30. They turned on the right at the mini roundabout in figure 31. After that, they turned on the left at the traffic light shown in the figure 32.

They turned on the left at the roundabout (figure 33) for reach the car park where the test finished.

The junctions are shown in the following figures.

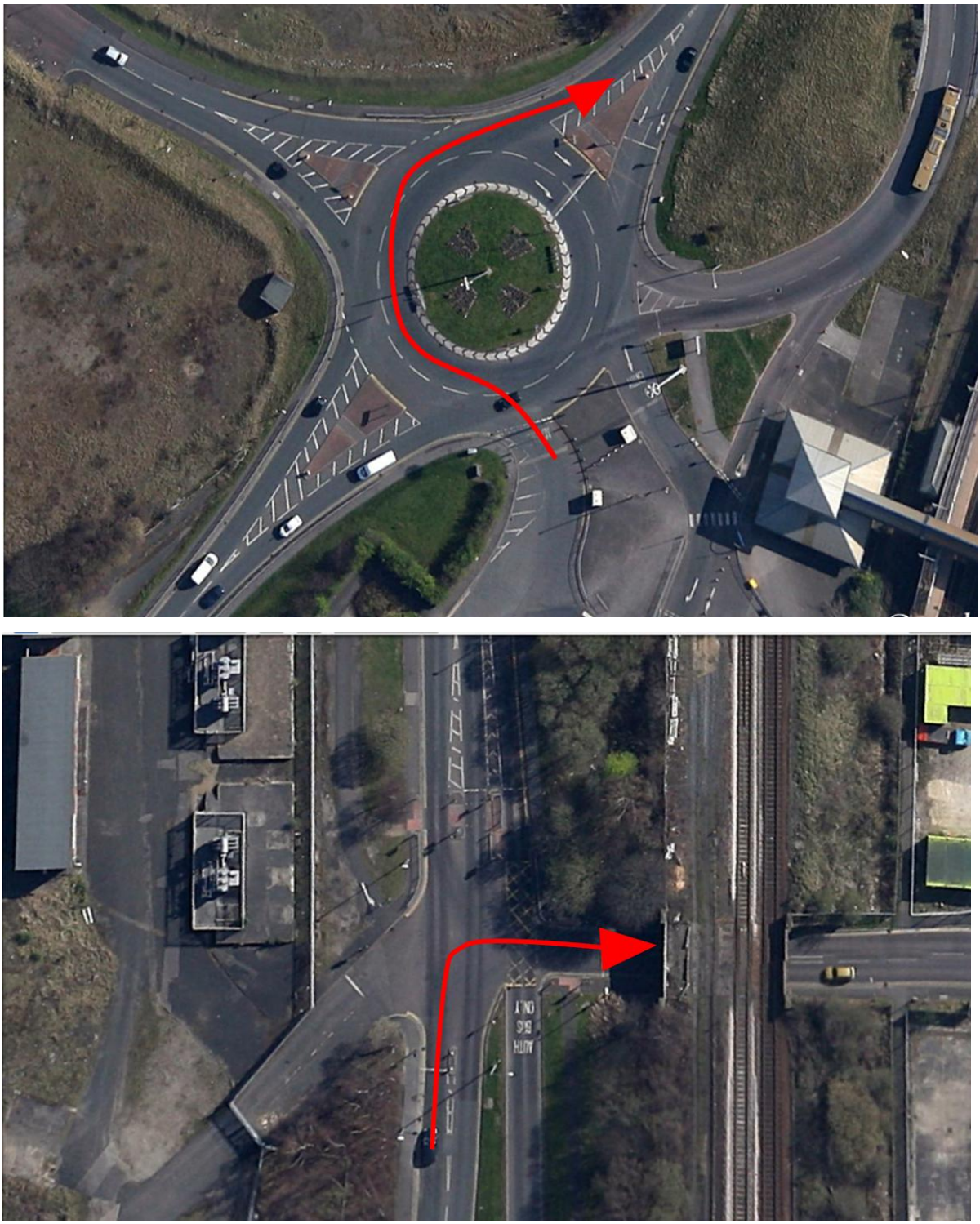

Figure 16 Turn on the right at the roundabout – Source: google earth

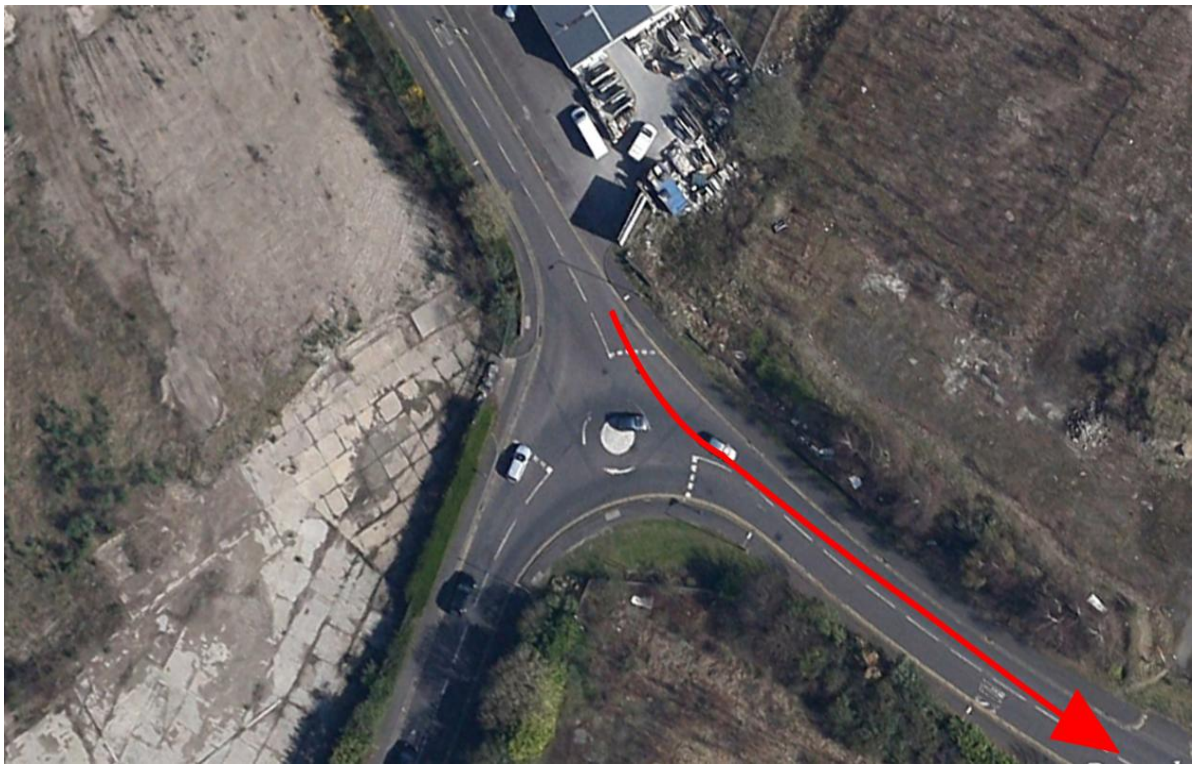

Figure 17 Turn on the right at the traffic light– Source: google earth

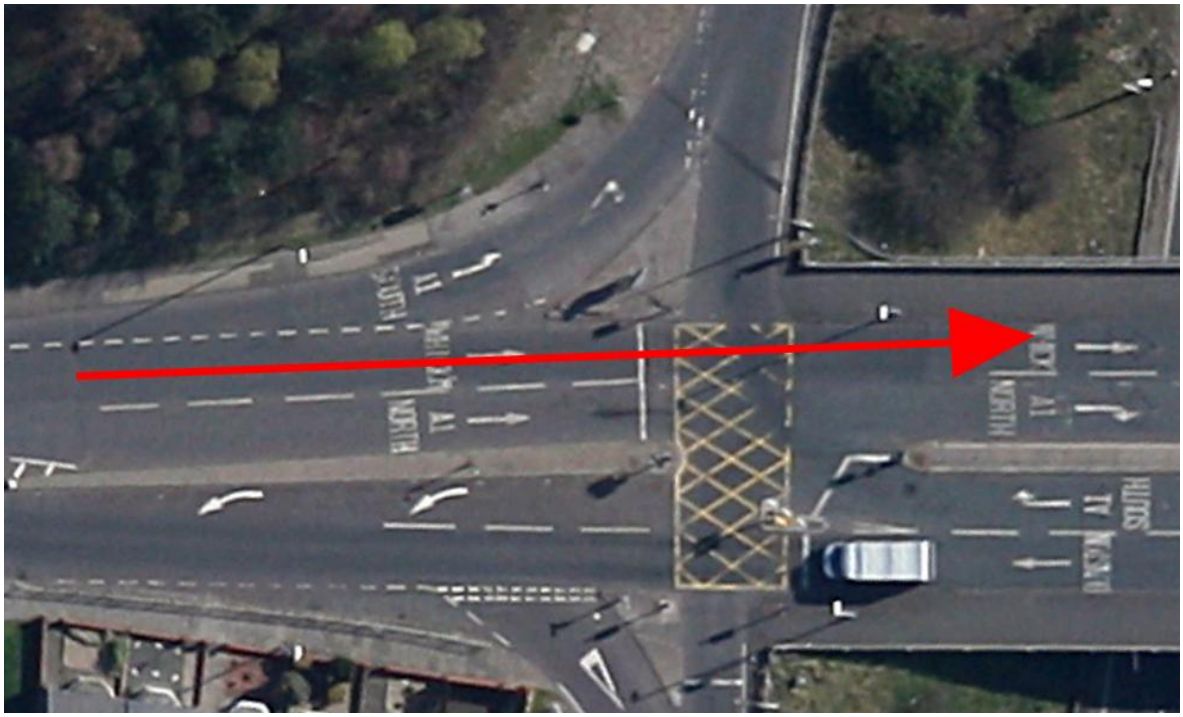

Figure 18 Straight on the left at the mini roundabout – Source: google earth

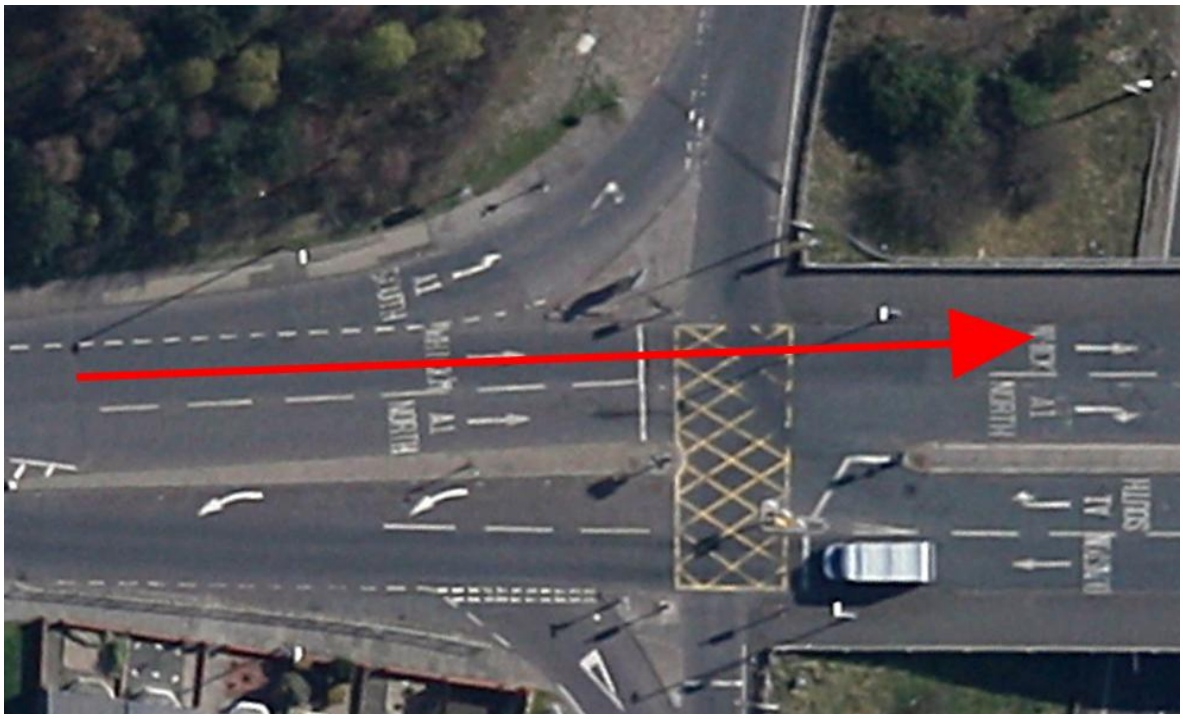

Figure 19 Straight on at the traffic light – Source: google earth

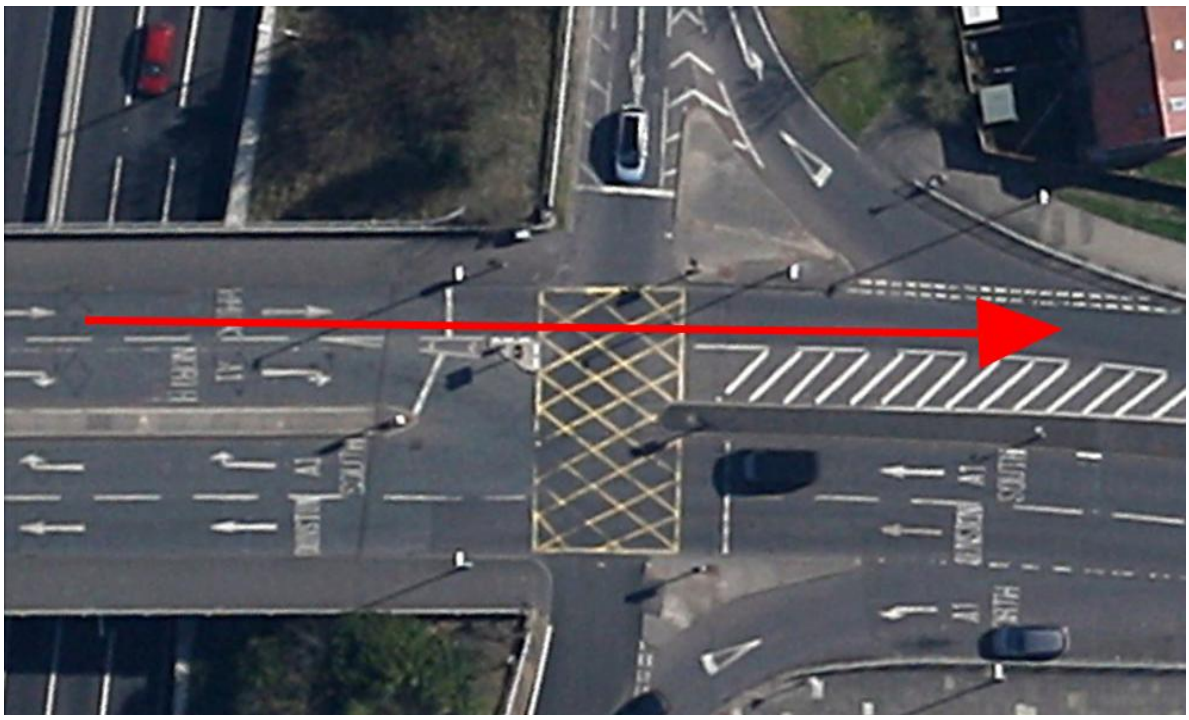

Figure 20 Straight on at the traffic light – Source: google earth

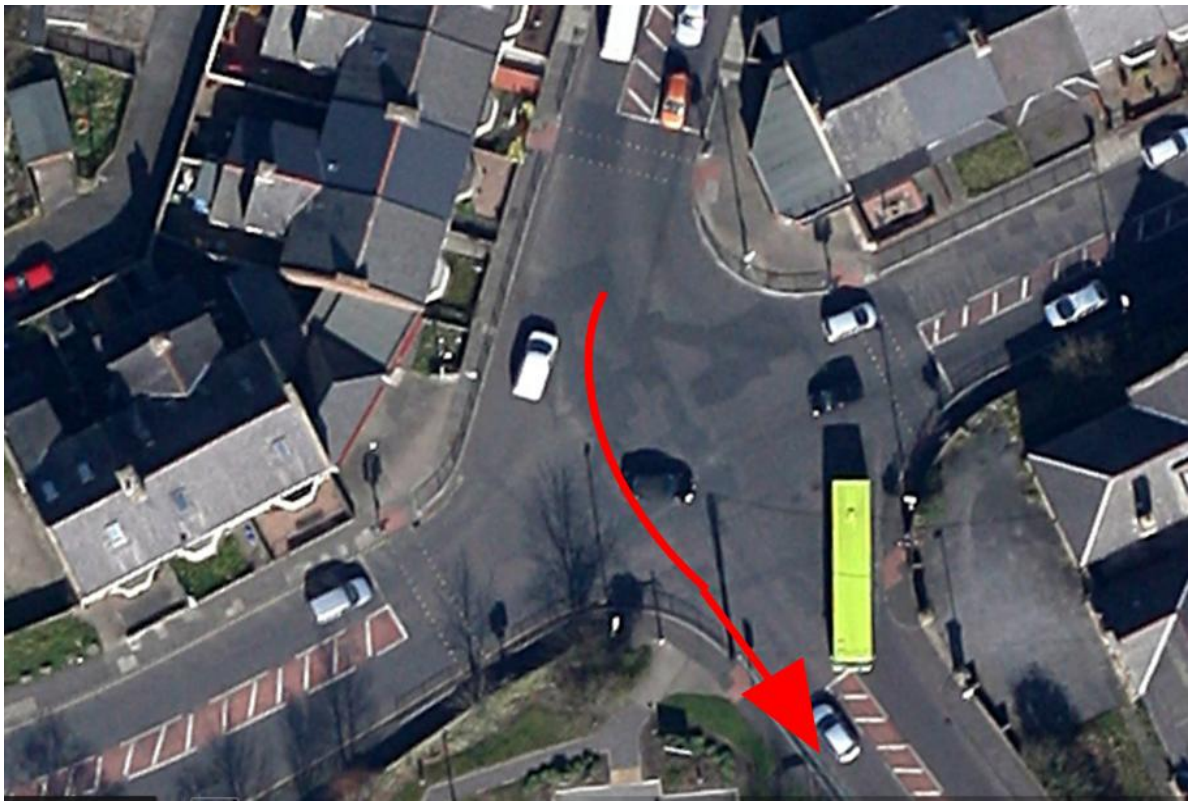

Figure 21 Straight on at the traffic light – Source: google earth

Figure 22 Turn on at the T junction – Source: google earth

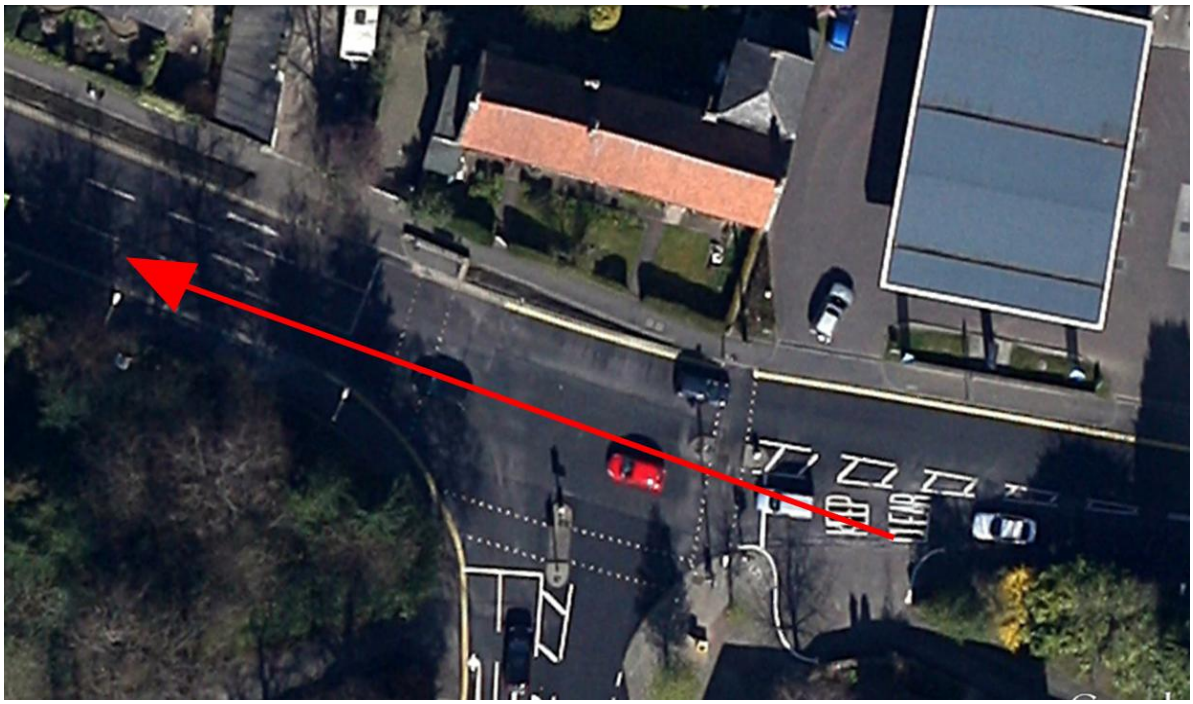

Figure 23 Straight on at the traffic light – Source: google earth

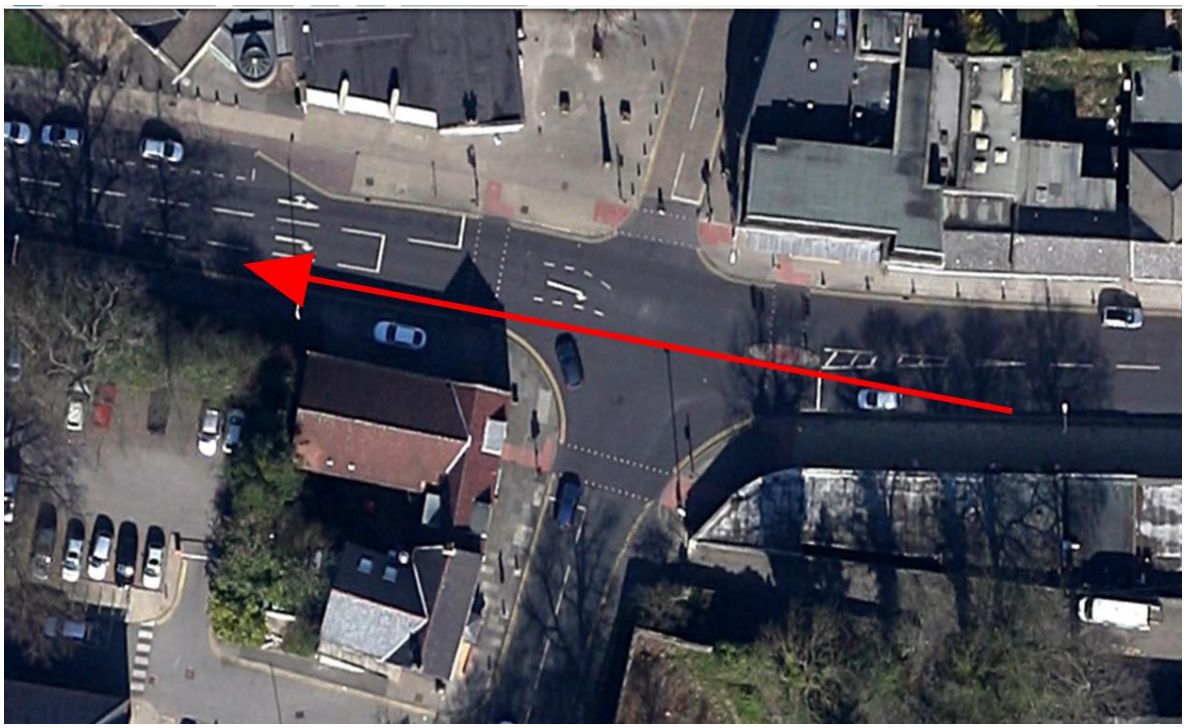

Figure 24 Straight on at the traffic light – Source: google earth

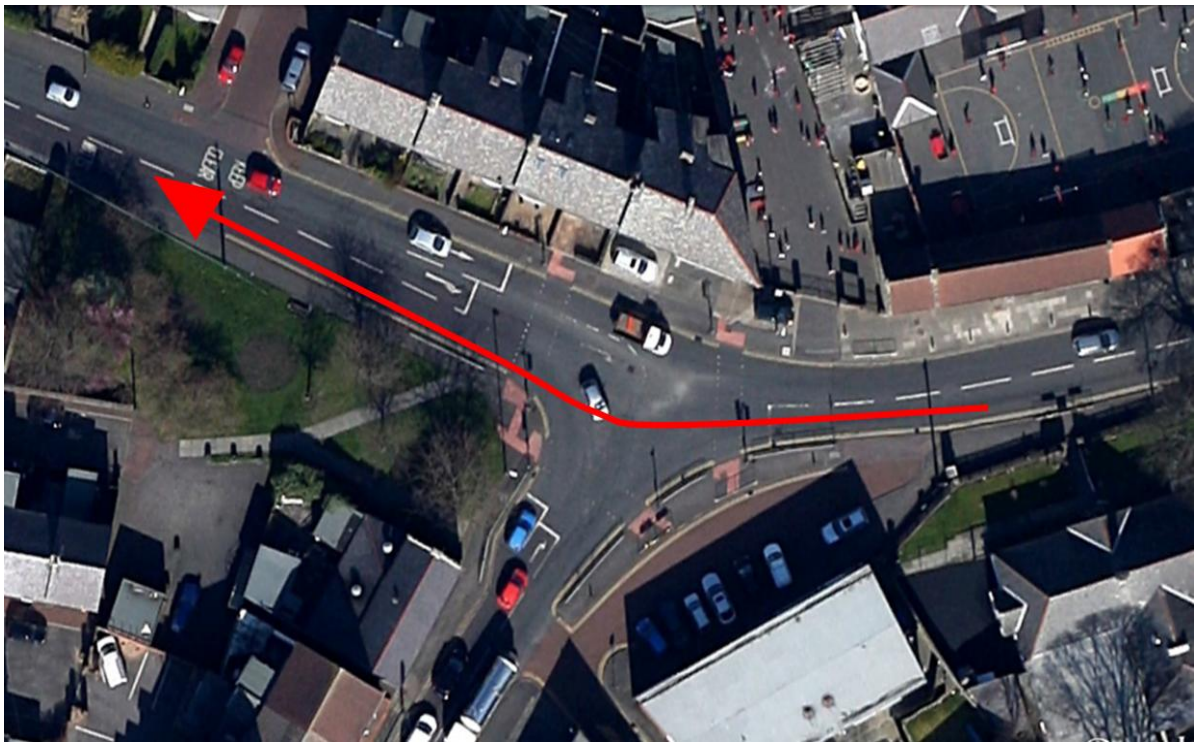

Figure 25 Straight on the right at the traffic light – Source: google earth

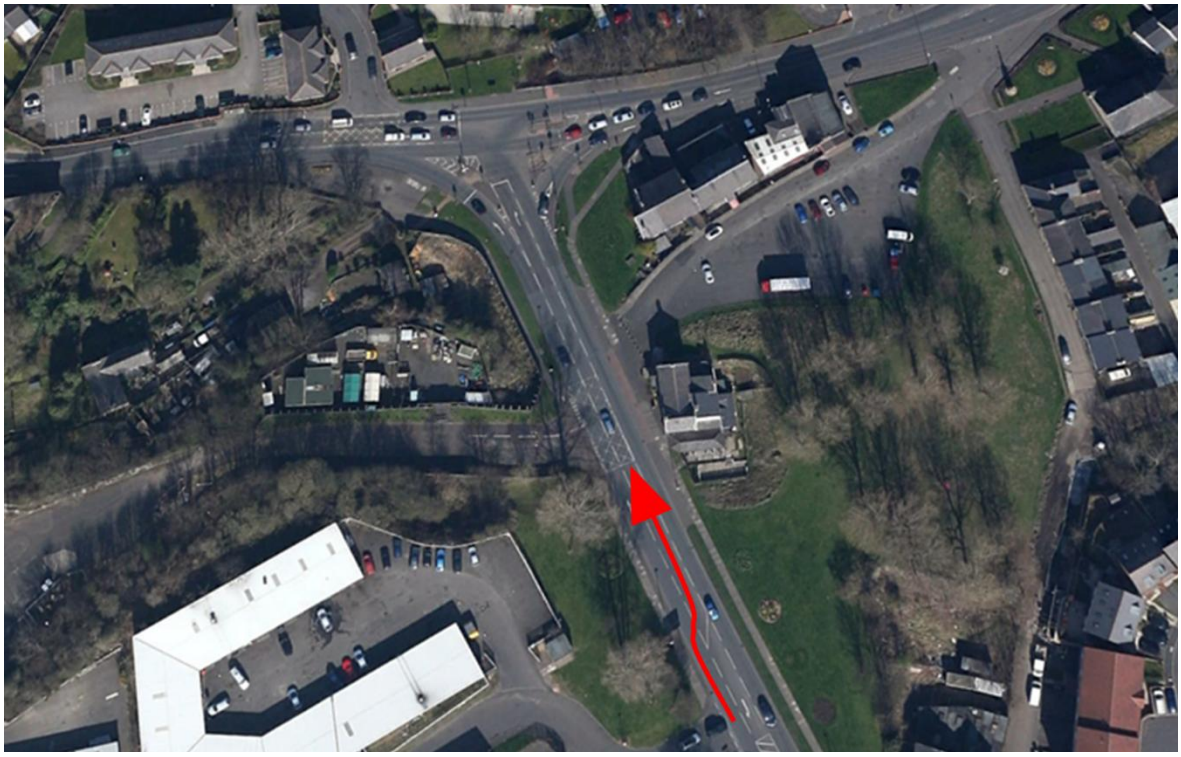

Figure 26 Changing lane – Source: google earth

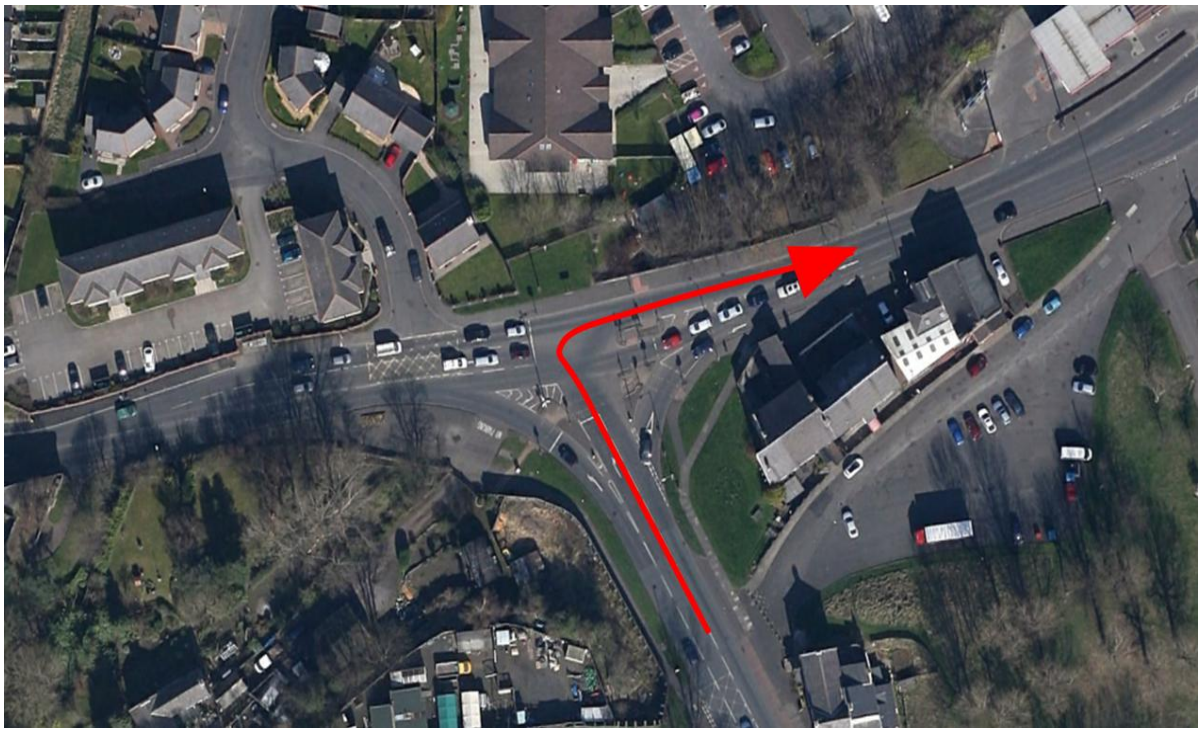

Figure 27 Turn on the right at the traffic light – Source: google earth

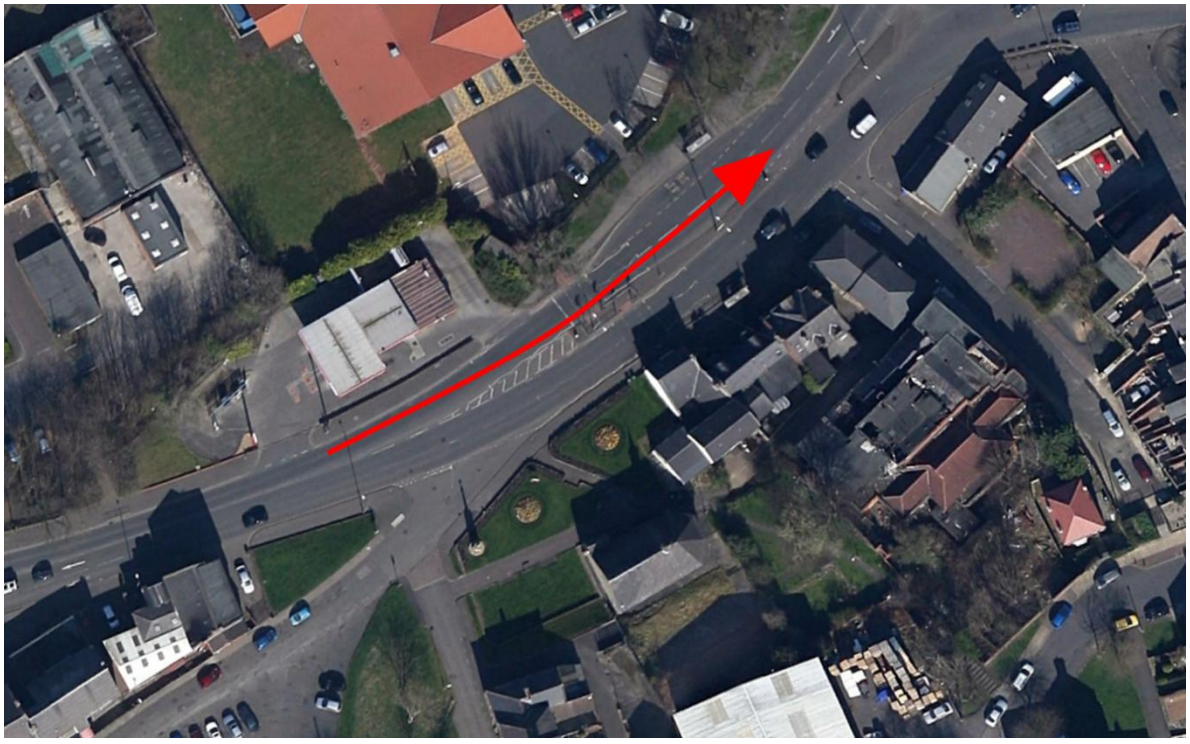

Figure 28 Straight on at the traffic light – Source: google earth

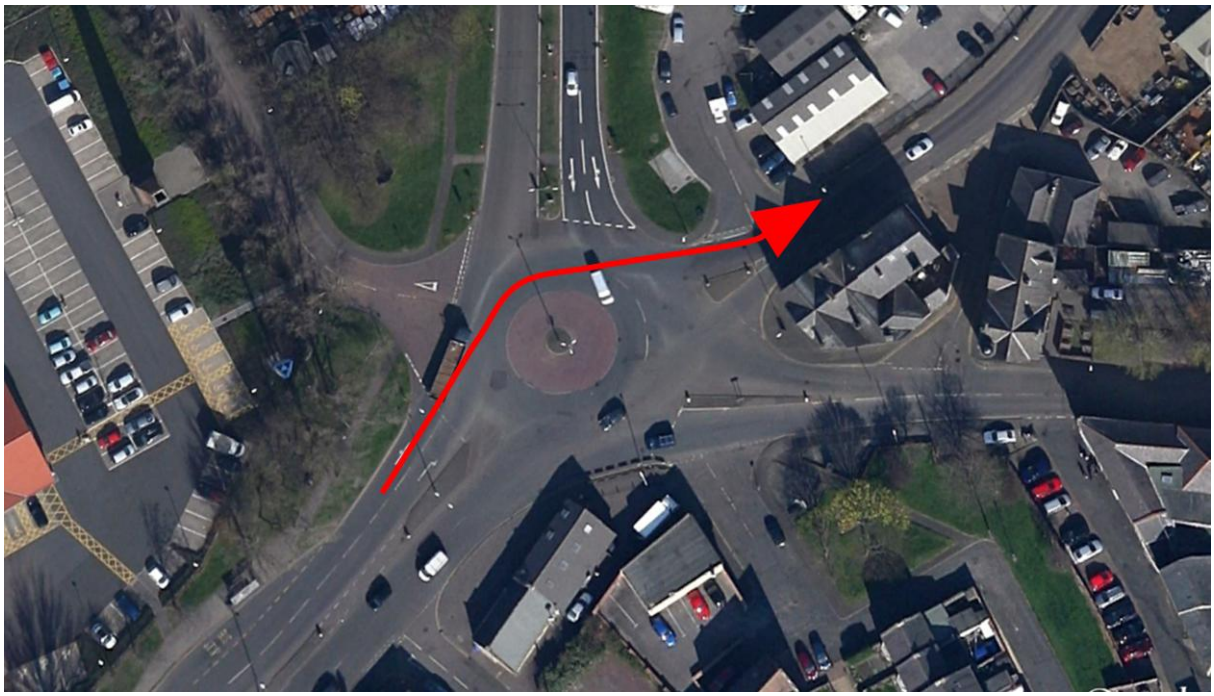

Figure 29 Straight on at the roundabout – Source: google earth

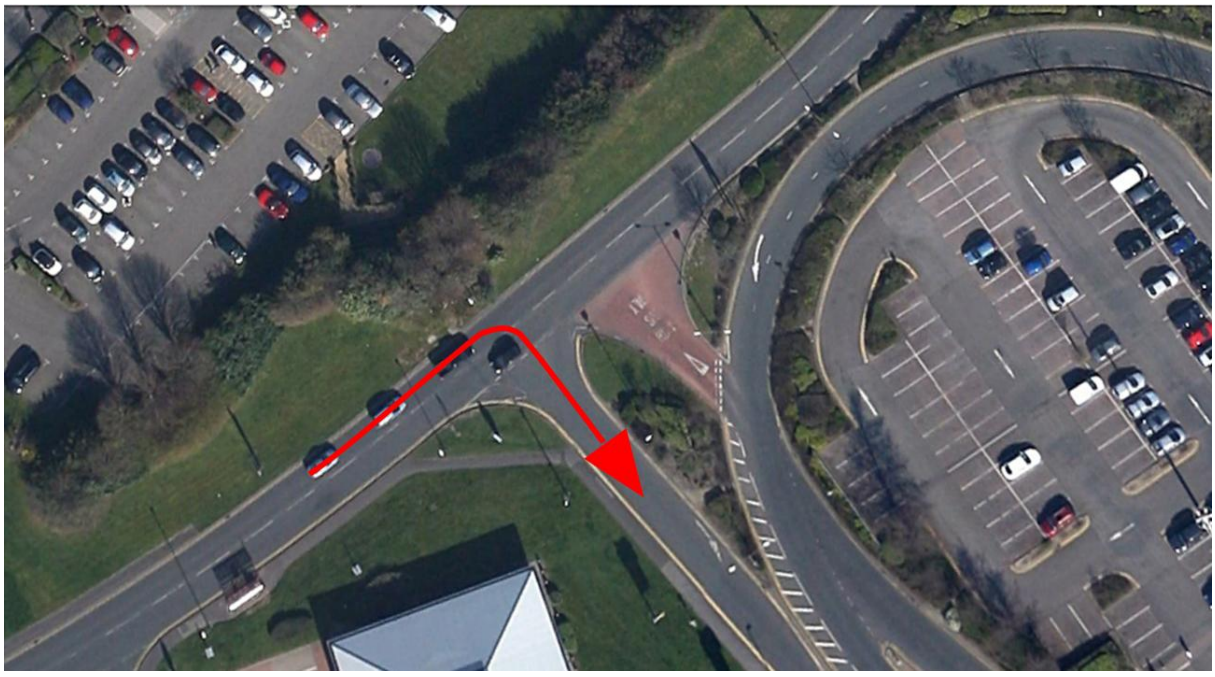

Figure 30 Turn on right at the marked junction – Source: google earth

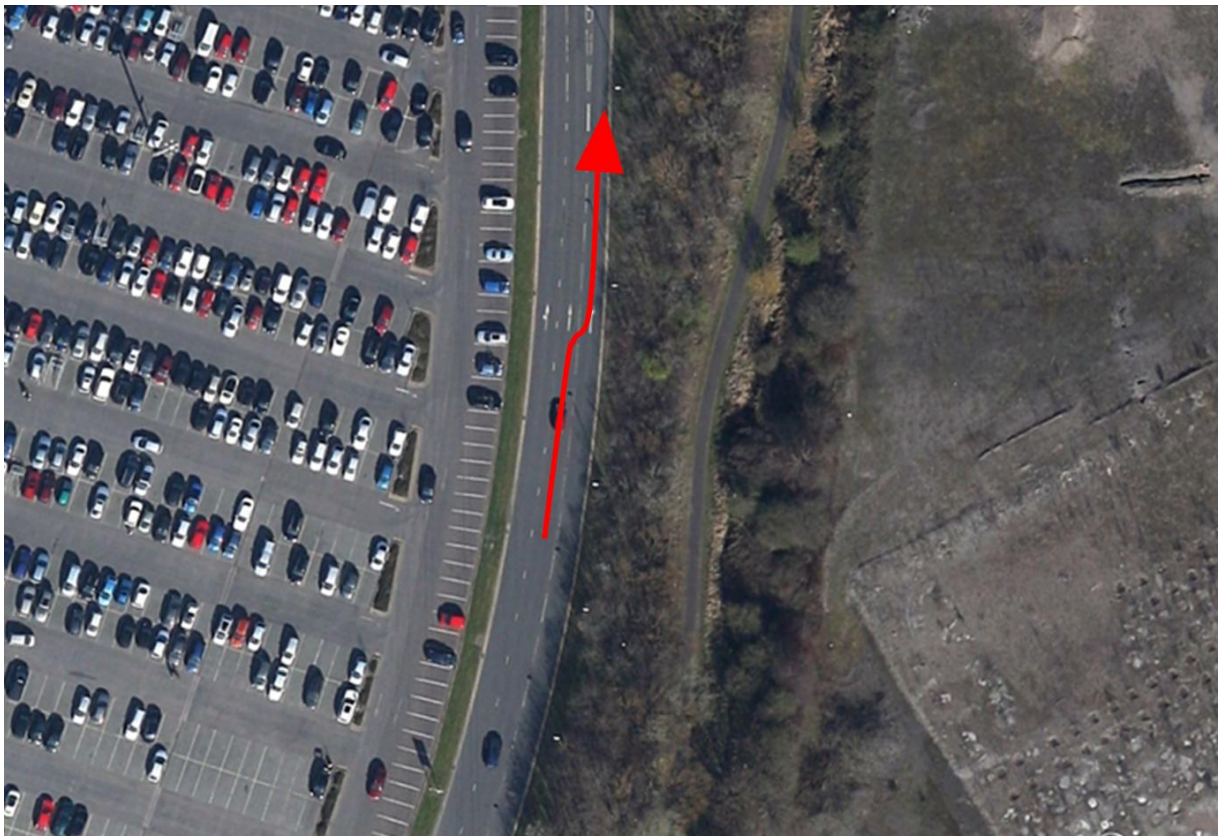

Figure 31 Changing lane – Source: google earth

Figure 32 Turn on the right at the traffic light – Source: google earth

Figure 33 Turn on the left at the mini roundabout – Source: google earth

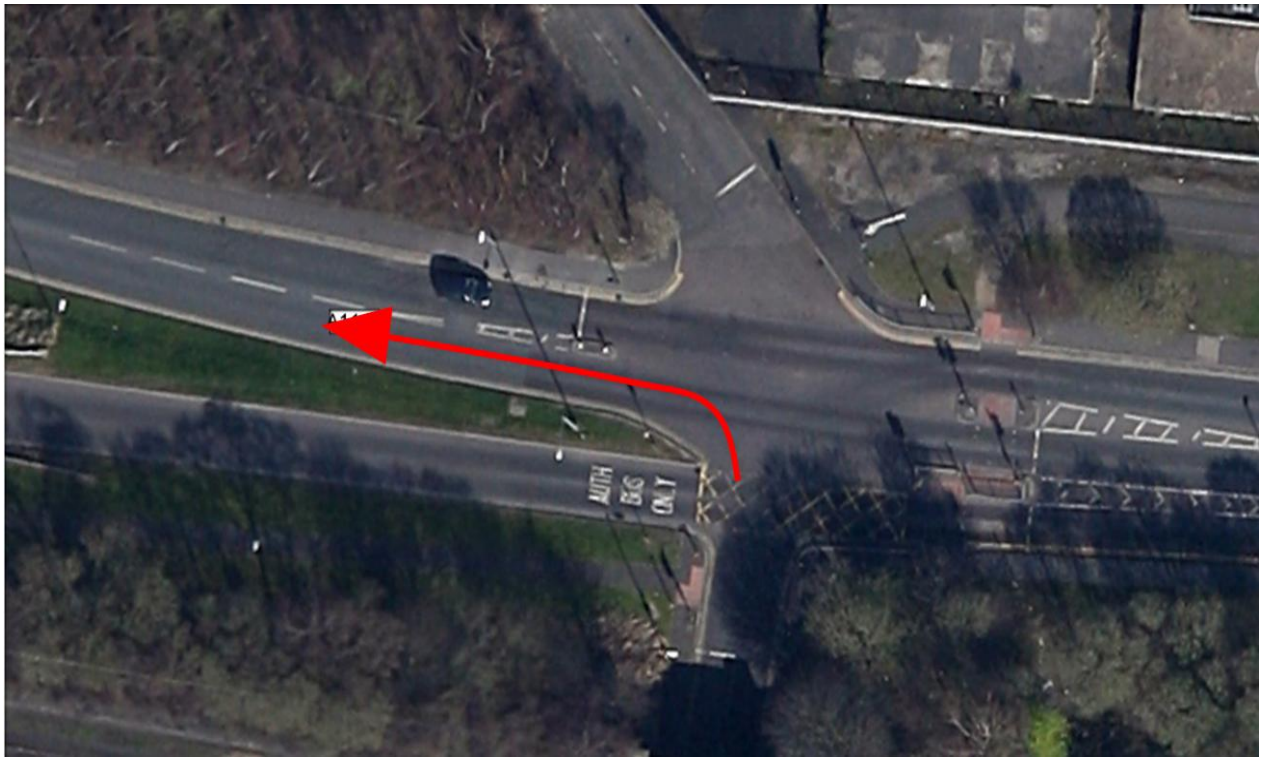

Figure 34 Turn on the left at the traffic light – Source: google earth

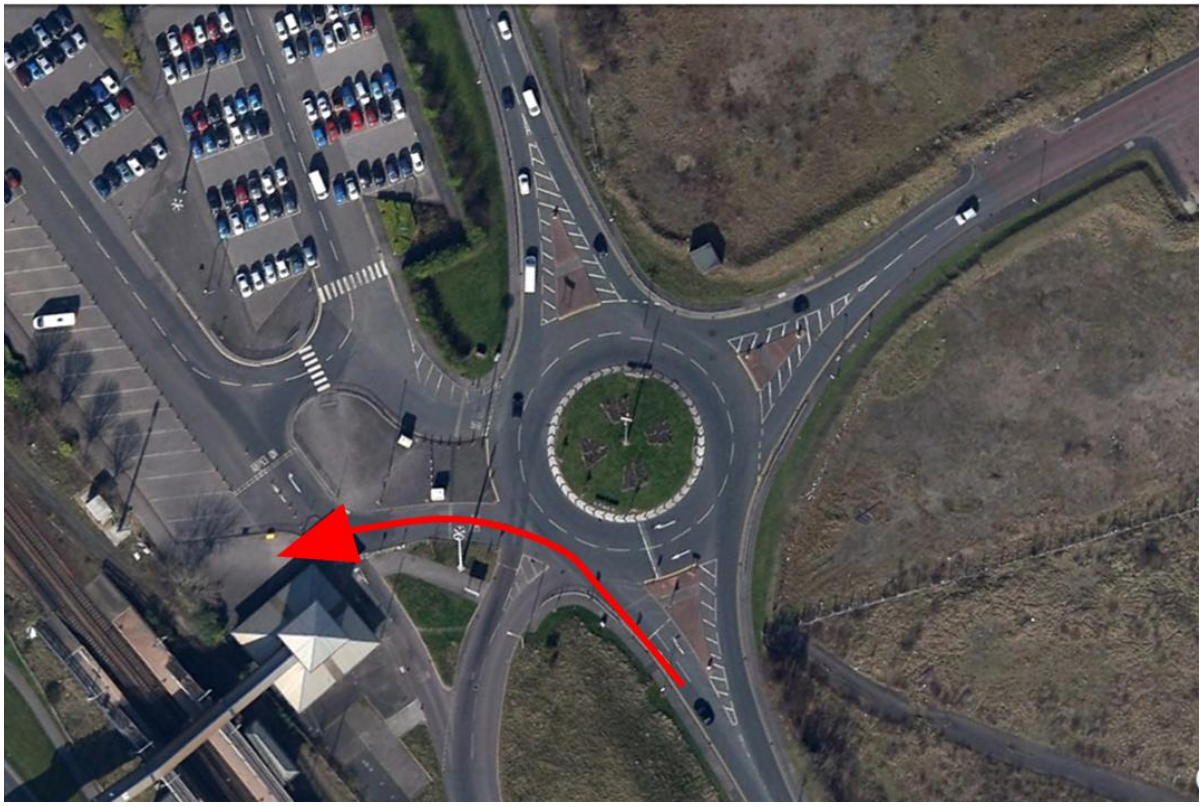

Figure 35 Turn on the left at the roundabout – Source: google earth

5.2.4. The vehicle used for the tests

The vehicle used was a Peugeot iOn, a totally electric car with a permanent magnet motor that delivers 47 kW or 64 hp from 3000 to 6000 rpm. The motor is rear mounted and acts on the rear wheels. There is also a system for recovering energy during braking.

The car is equipped with an automatic transmission, but with a mode switch lever.

Figure 36 Vehicle used for the trials.

5.2.5. The eye tracker

In order to analyze the elements observed by drivers during the test and to verify that they have paid enough attention to pedestrians and other vehicles during the tests; all drivers' eye movements were analyzed with an eye tracker.
This tool allows the eye tracking and allows to identify which visual stimuli were observed and which were neglected during the test and it measures the time required to perceive them. The instrument consists of three cameras, two of which are indicated in the figure below, they record the driver and monitor the gazes, the number and the duration of blinks and the pupil diameter, which have a direct relationship with the level of fatigue.

These cameras measure the number and magnitude of rotation of the neck, this variable is particularly important for the study of elderly drivers at junctions, because of the reduction in the amplitude of their visual field, they are forced to make several rotations of the head in order to perceive the stimuli at the ends of their visual field.

The third camera records the external driving environment and an internal part of the vehicle (dashboard, rear view mirror and speedometer), this was mounted in the passenger seat through a metal bracket, so as to be at the same height of the driver's eyes.

Figure 37 Camera of the eye tracker

Figure 38 Driver tested inside the vehicle whit the internal cameras

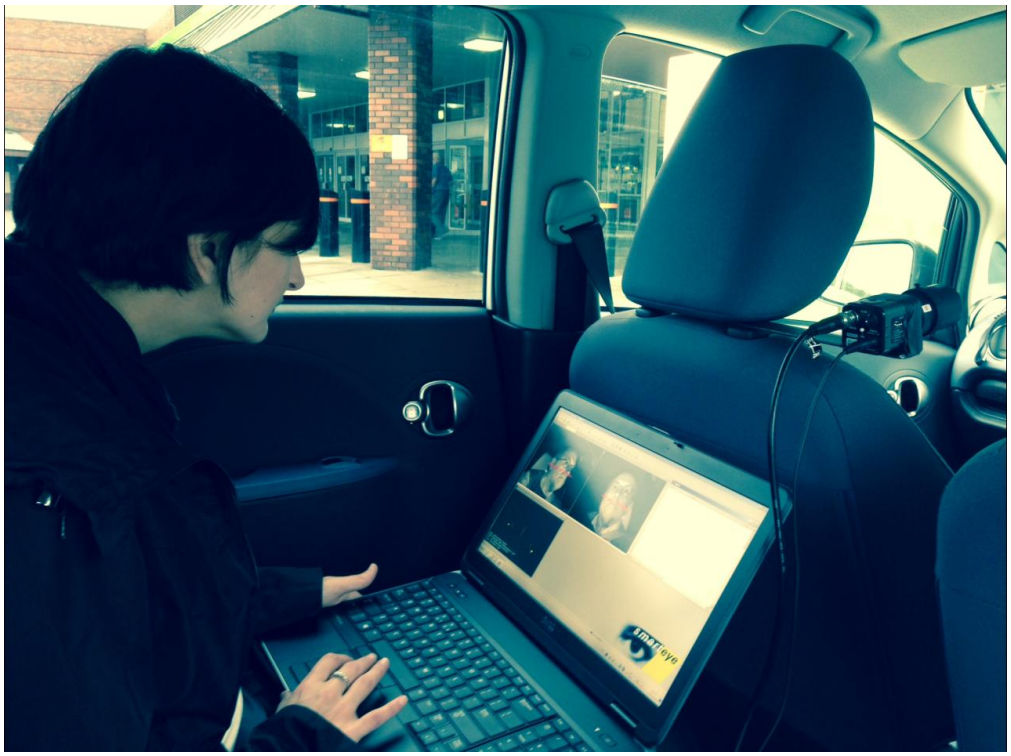

Figure 39 Phase of the calibration of the eye tracker

5.2.6. Operating conditions during tests

The road tests were performed during four weeks, from September 15 to October 28 2014, and during these days the meteorological conditions were similar. All tests were performed during day light hours. The date, time, and weather conditions of the tests are shown in the following table.

Table 8 Weather conditions during tests- Source: eurometeo

Driver ID	Date	Hour	Weather conditions
1	15/09/14	10:00-11:00	Cloudy
2	15/09/14	11:30-12:30	Cloudy
3	16/09/14	10:00-11:00	Cloudy
4	16/09/14	11:30-12:30	Cloudy
5	17/09/14	10:00-11:00	Cloudy
6	17/09/14	11:30-12:30	Cloudy
7	18/09/14	10:00-11:00	Cloudy

8	18/09/14	11:30-12:30	Cloudy
9	18/09/14	14:30-15:30	Cloudy
10	22/09/14	10:00-11:00	Mostly cloudy
11	22/09/14	11:30-12:30	Mostly cloudy
12	22/09/14	14:30-15:30	Mostly cloudy
13	24/09/14	11:30-12:30	Partly cloudy partly sunny
14	24/09/14	14:30-15:30	Mostly cloudy
15	25/09/14	10:00-11:00	Cloudy
16	25/09/14	14:30-15:30	Partly cloudy partly sunny
17	26/09/14	10:00-11:00	Mostly cloudy
18	26/09/14	11:30-12:30	Mostly cloudy
19	29/09/14	10:00-11:00	Mostly cloudy
20	29/09/14	11:30-12:30	Mostly cloudy
21	30/09/14	10:00-11:00	Mostly cloudy
22	30/09/14	11:30-12:30	Partly cloudy partly sunny
23	01/10/14	10:00-11:00	Partly cloudy partly sunny
24	01/10/14	14:30-15:30	Cloudy
25	02/10/14	10:00-11:00	Clear
26	27/10/14	10:00-11:00	Partly cloudy partly sunny
27	27/10/14	11:30-12:30	Cloudy
28	27/10/14	14:30-15:30	Cloudy
29	28/10/14	10:00-11:00	Mostly cloudy
30	28/10/14	11:30-12:30	Mostly cloudy
31	28/10/14	14:30-15:30	Cloudy with rain

5.2.7. Evaluation of driving performance

During the tests drivers' performances have been analysed, on basis of the studies previously described (Justiss, 2005) a standardized form was filled in for evaluate the performance of the manoeuvres and to measure the number and the severity of the errors.

The execution of the manoeuvres was evaluated with a score ranging from 0 to 3 and it corresponds to the following ratings:

3 if no error was observed, the driver is not considered dangerous at all times;

2 if one or more errors were observed, the driver is not considered dangerous, but with restrictions and recommendations;

1 if one or more errors were observed, and if a verbal warning to change the driving behaviour was necessary, the driver is at high risk (but reversible);

0 if one or more errors were observed, and physical intervention of the examiner was necessary or if there have been any violations of the road rules, the driver is at high risk (irreversible).

The table 9 shows the ratings given to each driver based on their driving performance and mistakes made during the tests.

Table 9 Driving ability evaluation during tests

Driver ID	**Driving ability evaluation**	**Errors**		
1	3			
2	3			
3	2	He/ She Stayed ever in the central lane on the roundabout	incorrect approach and no indicator at the mini roundabout	
4	2	He/ She Indicated for turn left in the park and a car was arriving		

5	2	He/ She stayed ever in the central lane on the roundabout		
6	0	He/ She Crossed with the red traffic light	when He/ She came out of the car park He/ She was running over a pedestrian	Speeding
7	2	indicator in the opposite side going in / and no indicator going out every time crossed a roundabout		
8	3			
9	3			
10	3			
11	3			
12	2	incorrect approach and no indicator in the roundabout	He/ She straight on the traffic light and not on the left	
13	1	He/ She overtook cyclist going in the opposite lane	He/ She changed lane without indicator when he must straight on	
14	3			
15	3			

16	0		NO indicator in the roundabout	He/ She went out to the roundabout in the entry lane
17	0	He/ She was not able to stop in the middle of the junction	He/ She crossed traffic light when orange light was finishing and was in the middle of the junction when was red	He/ She cannot turn the steering wheel with a single rotation, but He/ She performs many small movements
18	3			
19	3			
20	3			
21	3			
22	2	NO indicator in the roundabout	He/ She asked the correct lane because was going in the bus lane	
23	3			
24	1	He/ She overtook a lorry in a curve when He/ She couldn't see behind	Speeding	He/ She crossed with orange and finished the manoeuvre with red light
25	3			
26	2	incorrect approach in the roundabout		

27	3			
28	3			
29	3			
30	2	incorrect approach in the roundabout	Speeding	
31	2	Speeding		

5.2.8. Results of the questionnaire Driving Ability Index: frequency analysis

All drivers who have been tested were volunteers, to be eligible for the study, they were required to be experienced drivers, holding a license for at least 10 years.

The sample tested by road tests and then interviewed with the questionnaire consists of 31 drivers 28 of them aged between 60 and 86 years, the average age in the sample was 70.39 years (standard deviation of 6.396 years). Three drivers under the age of 60 were included in the same test, some of them have special certifications that prove their ability to drive (such as IAM, or licences for the ambulance), these experienced drivers were tested with the aim to make comparisons between driving performance in both age groups. The average age of experienced drivers is 55.67 years. In the following, frequency analysis, the drivers of the two age groups were considered separately.

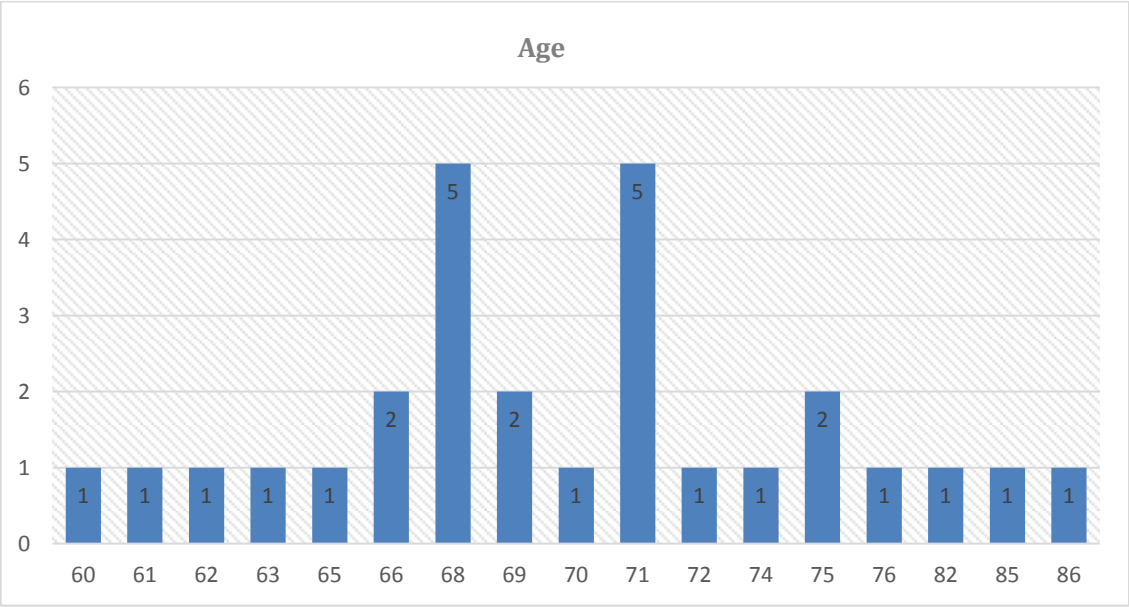

Figure 40 Drivers tested grouped by age

In the survey five women and twenty-three men were included over the age of 60 years and three men under the age of sixty.

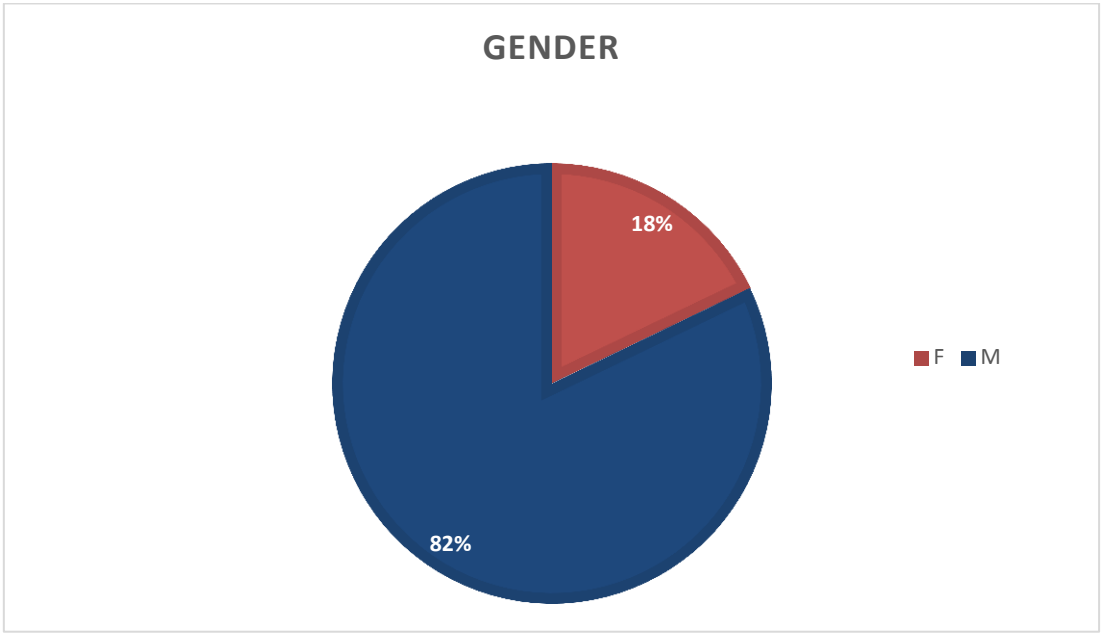

Figure 41 Drivers tested grouped by gender

The majority of elderly drivers tested (46.4%) travel for most of the time with other people, 25% of them travel sometimes with other persons (drivers 7), 25% travel occasionally with other people, and only one always travel alone. The experienced drivers have given different answers, their responses were: Never, sometimes and most of the time.

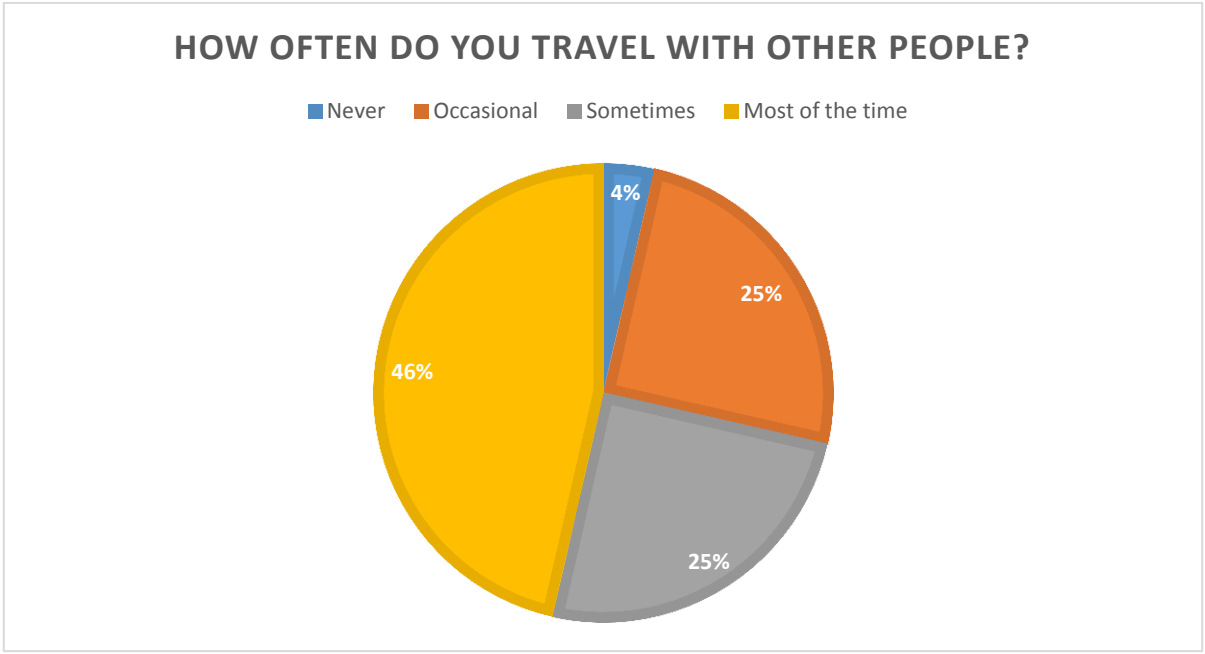

Figure 42 Reponses of drivers to the question: "How often do you travel with other people?"

All drivers involved in the survey are usually drivers of the vehicle and not passengers, when they travel by car.

92.86% of drivers (26 drivers) are retired and two of them are still working. Among the experienced drivers only one was still working at the time of the test.

46.4% of drivers surveyed got an academic degree; nine drivers have achieved the "A levels and equivalents", which corresponds to the “diploma”; three have achieved the "GCSE / O-level and equivalents", which corresponds to the middle school, and three answered "no qualification" that corresponds to the primary school.

Among the experienced drivers one has a degree and the other two have "A level or equivalent".

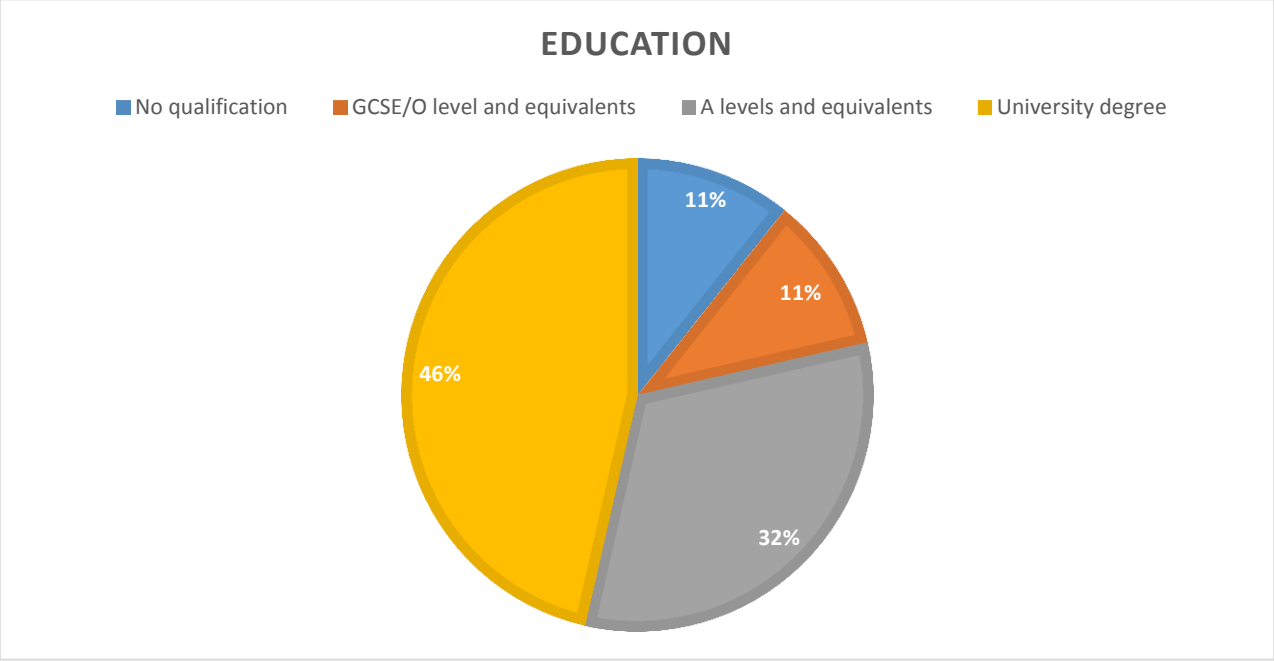

Figure 43 Education for the driver surveyed

Only one driver included in the survey currently smoke, 67.9% have never smoked (19 drivers), eight of them are ex-smokers. None of the experienced drivers was smoking at the time of the study, but two of them are ex-smokers.

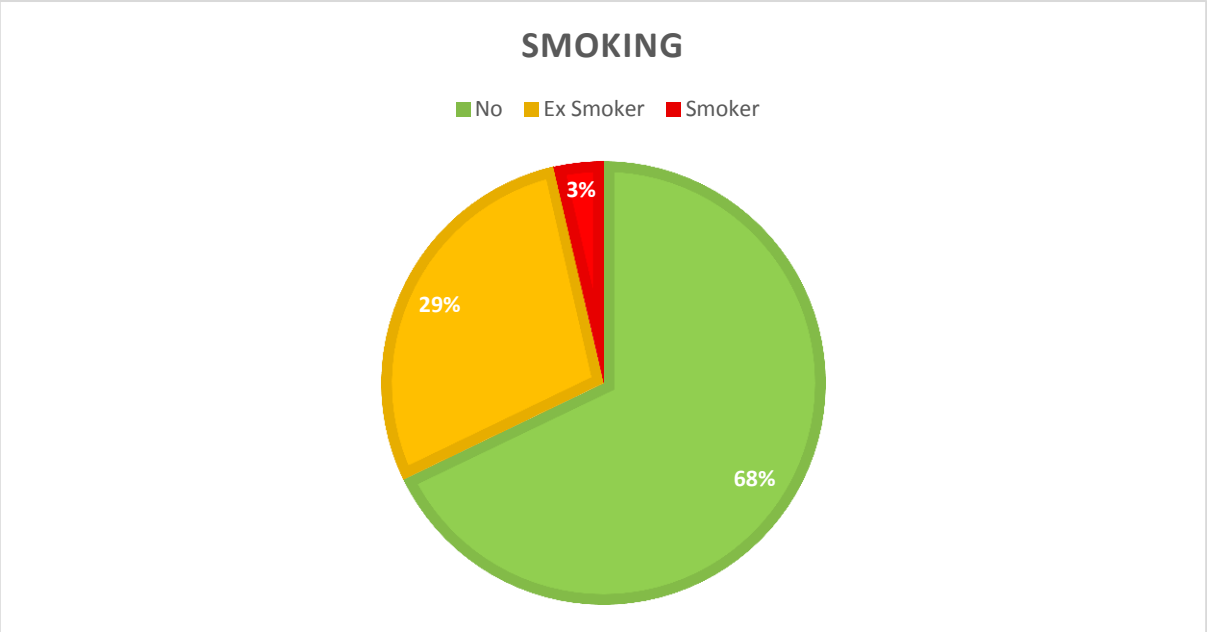

Figure 44 Smoking in the drivers tested

Regarding alcohol consumption, 32.1% of drivers consumes alcohol 2 or 3 times a week, 25% consume it monthly, 7 of them (22.7%) consume alcohol 4 or more times a month, two drivers consume alcohol from 2 to 4 times a month and three drivers never consume alcohol.

Two experienced drivers consume alcohol 2 or 3 times a week, and a driver drinks alcohol 2 or 4 times a month.

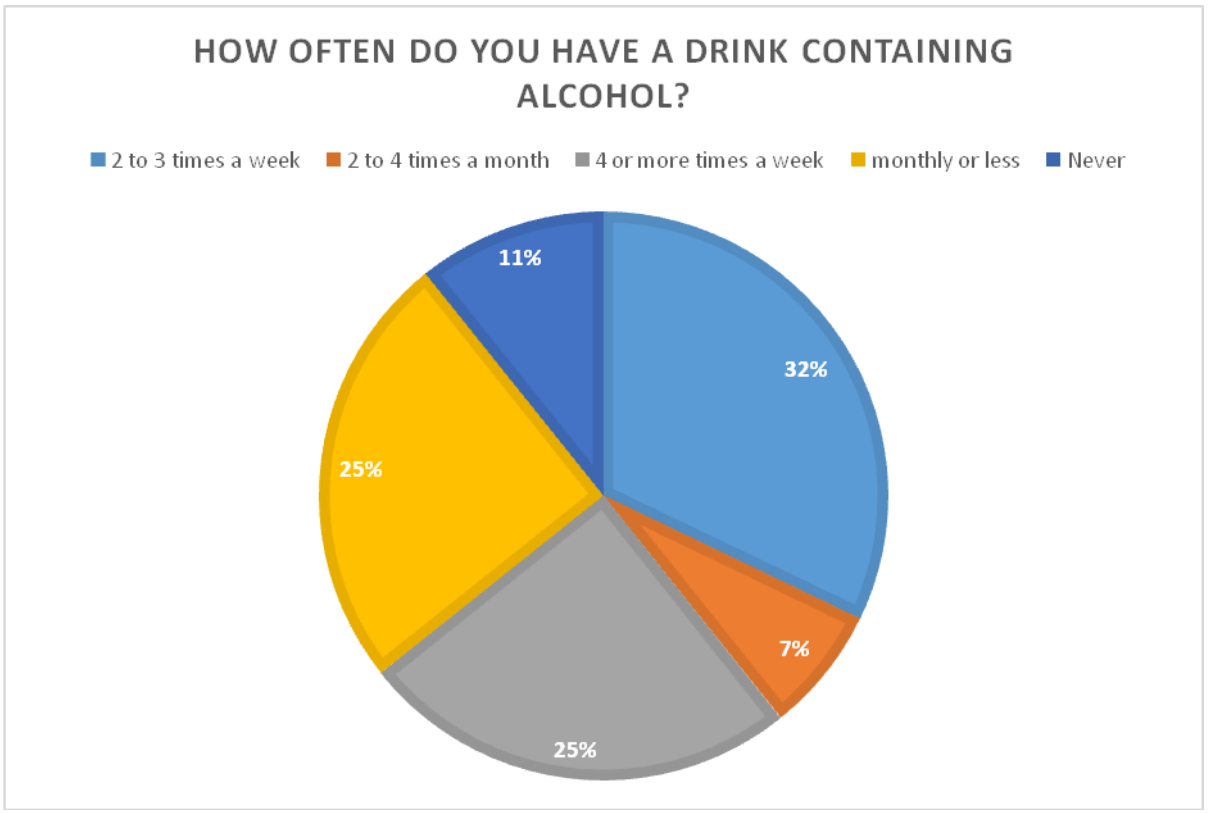

Figure 45 Alcohol consumption

67.9% of the drivers when drinking consume an average of one or two units of alcohol, six of them consume on average 3 or 4 units and two drivers consume 5 or 6 units. All experienced drivers consume 3 or 4 units of alcohol.

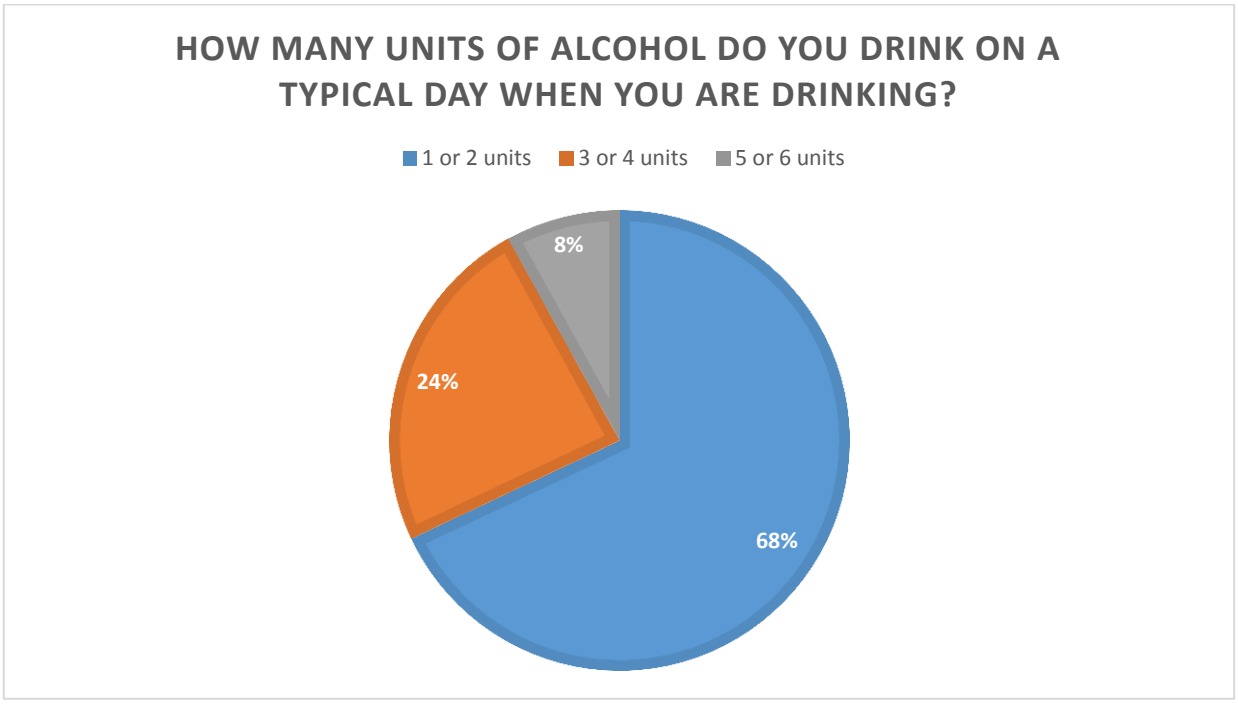

Figure 46 Quantity of alcohol drank typically

It has been evaluated the level of satisfaction with the quality and the amount of sleep they get, in a scale from 1 (unsatisfied) to 5 (very satisfied); six drivers have declared the highest satisfaction level. 35.7% (10 drivers) reported a satisfaction level of 4; for 14.3% the degree of satisfaction is 3, the level 2 was chosen by four drivers, four drivers (14.3%) said they were unsatisfied and they chose the minimum level (1). The average satisfaction level in the sample is 3.36 (SD = 1.36). All experienced drivers rated their satisfaction level as 4.

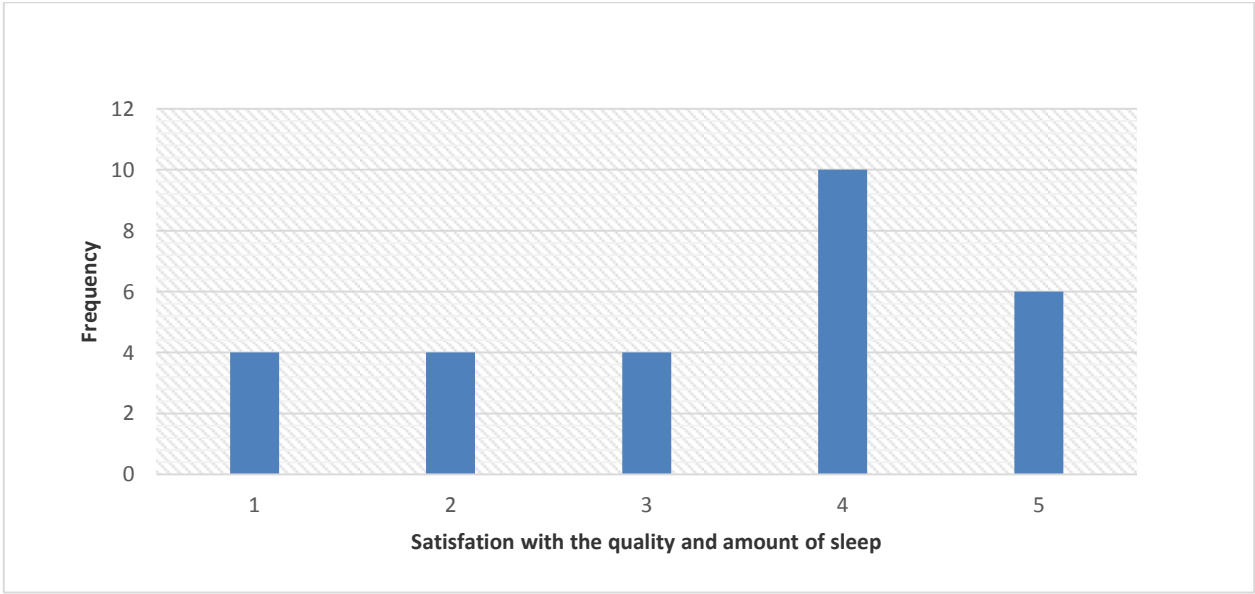

Figure 47 Satisfaction with the quality and amount of sleep

Usually the drivers tested have been driving from a minimum of 31 to a maximum of 61 years, the average value in the sample is 48.26 years. The experienced drivers have been driving on average from 37.33 years and it ranges from a minimum of 36 to a maximum of 38 years.

Within the sample the average mileage travelled is of 44.21 miles a day (SD = 60.02) and ranges from a minimum of 5 miles a day to a maximum of 250 miles a day. Drivers under the age of 75 years travel on average 39.45 miles a day, those aged over 75 travel on average 61.67 miles a day. The experienced drivers travel on average 23.33 miles a day.

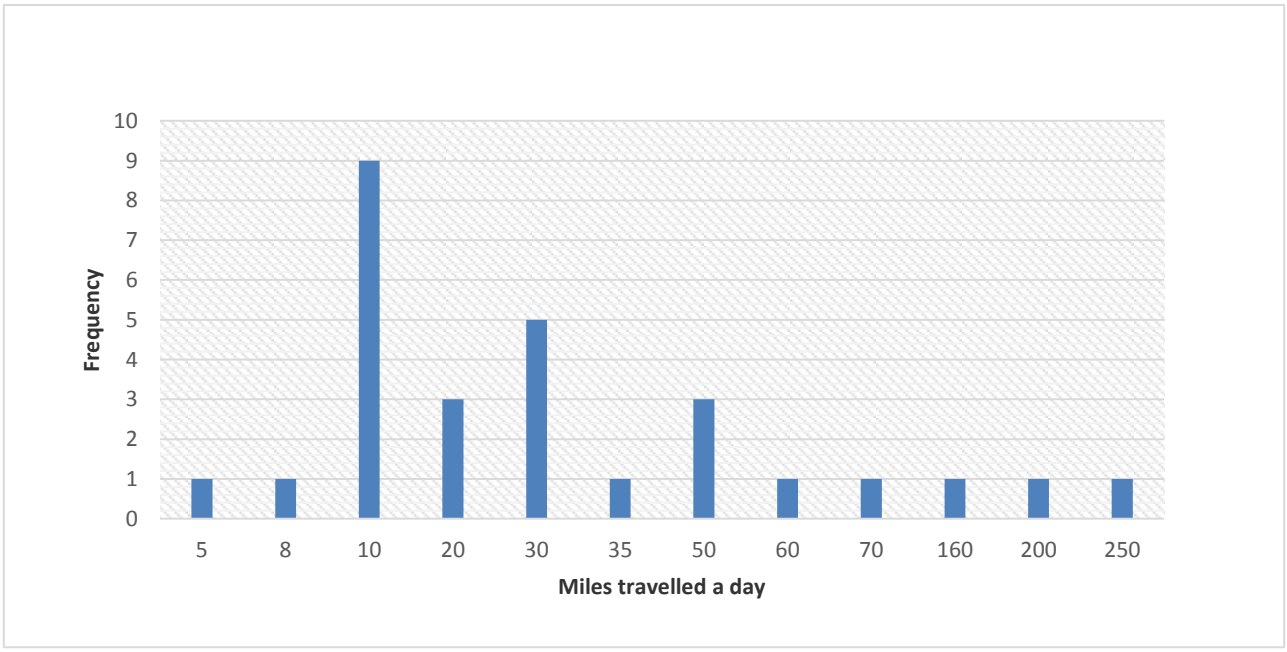

Figure 48 Mileage travelled a day by drivers tested

The majority of drivers (32.1%) travel annually from 5001 to 8000 miles (from 8048.33 to 12874.75 km); 21.4% travel from 2001 to 5000 miles (from 3220.3 to 8046.72 km), 17.9% travel from 8001 to 10,000 miles (from 12876.36 to 16093.44 km), and eight drivers travel more than 10,000 miles (16093.44) per year. None of them travels 2000 miles (3218.67 kilometers) or less per year. The experienced drivers travel a different mileage, ranging from 5001-8000 to more than 10,000 miles.

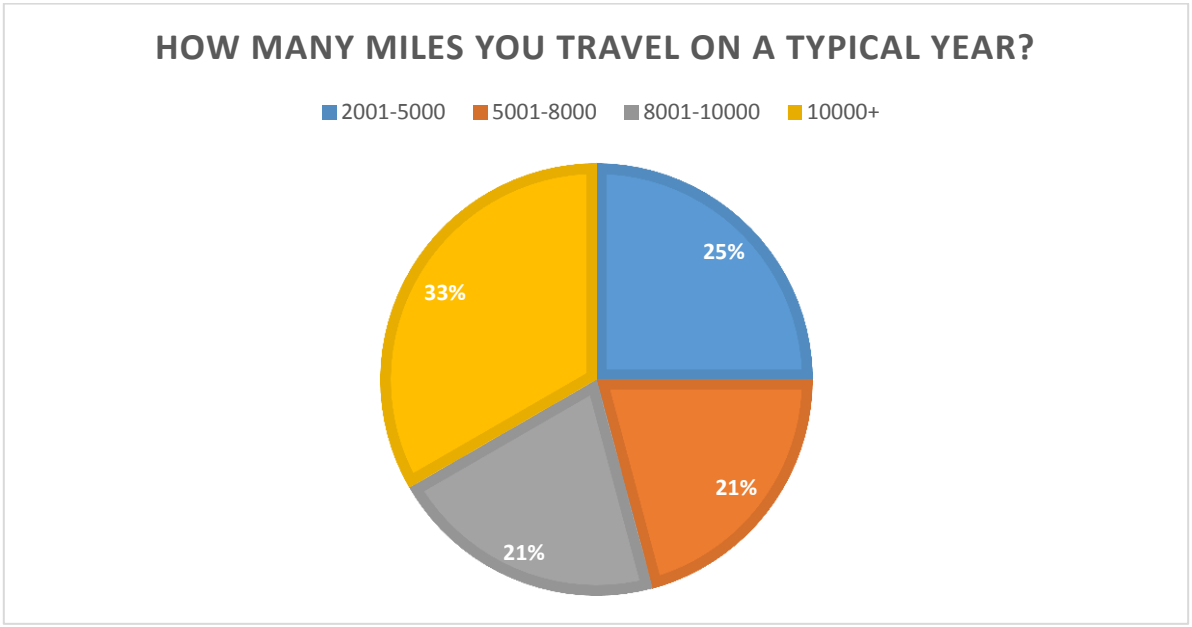

Figure 49 Mileage travelled per year by drivers tested

Drivers use their vehicles mainly in urban areas (54.46%) and only 38.21% of the trips take place in suburban areas or for long trips.

Even experienced drivers travel mainly in urban areas (55%) than in suburban areas (45%), but the difference is very low.

Among the drivers interviewed, 92.86% (26 drivers) have never given up driving for more than three months; two of them have not driven for three months since they have obtained their driver's licence as a result of a surgical operation.

Among the experienced drivers only one has not driven for more than three months because he was enlisted in the army.

For 32% of the sample, the size of the engine of the vehicles used is greater than 2000 L, in 21.4% of the sample it is between 1.4 and 1.6 L, for 21.4% the size of the engine is between 1.7 and 1.9 L, vehicles with engine size between 1.0 and 1.3 L are used by four drivers, and only 3 drivers (10.7% of drivers) drive vehicles with a cylinder capacity lower than 1.0 L.

The experienced drivers use powerful cars, in fact, two of them have a vehicle with the engine bigger than 2 L, and one of them has a vehicle with a cubic capacity between 1.7 and 1.9 L.

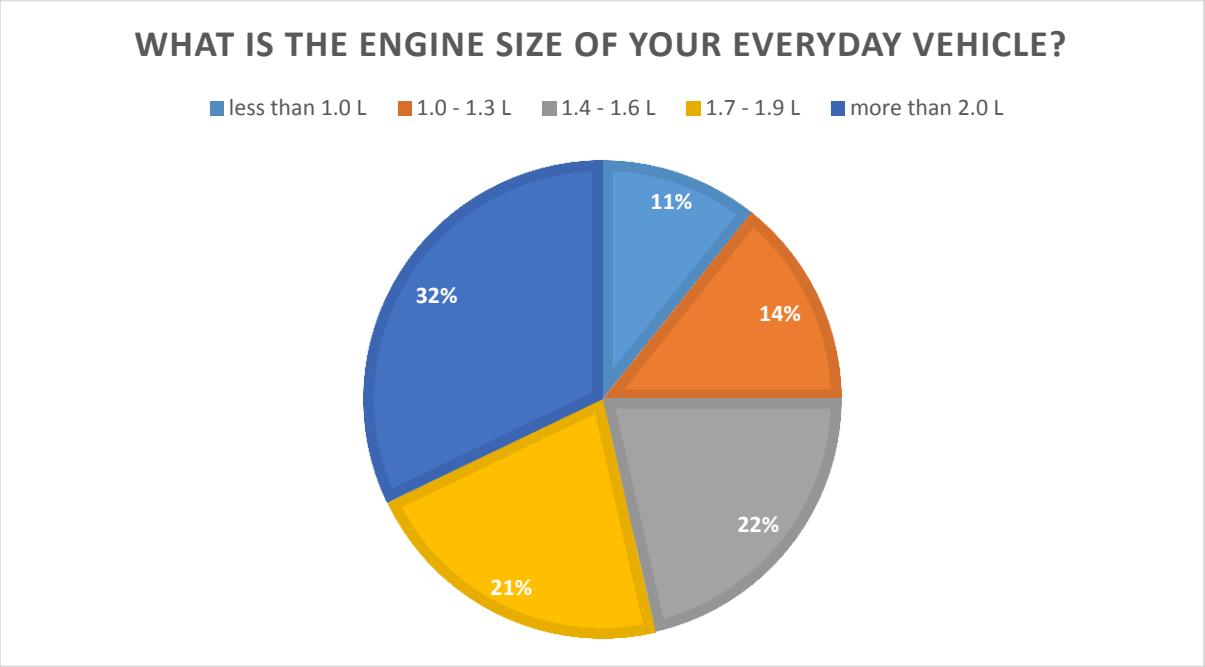

Figure 50 Size of the engine of vehicles used by drivers tested

The average age of the vehicles used was 6.04 years (SD= 5.81), and it ranges from a minimum of a few months to a maximum of 27 years. The average age of vehicles used by experienced drivers is 6.33 years.

Eleven drivers have a qualification different from the normal driving licence, some are members of the IAM and they are drivers of advanced level, one has the licence of category D1 to drive buses. Two experienced drivers have a driving qualification.

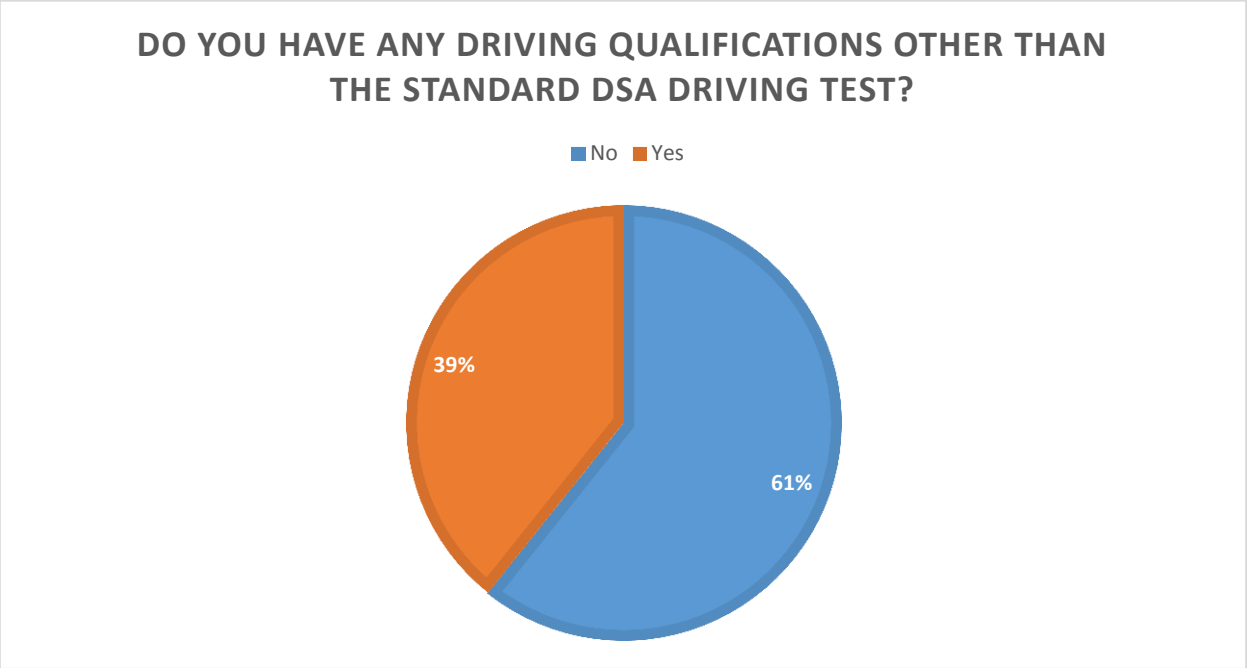

Figure 51 Driving qualification

Usually all drivers tested drive the car; 17 have driven a motorcycle, 23 of them have diven a van, a minibus or a camper, 21 drivers have driven a sports car, 3 of them have driven a lorry, a bus or a coach, and only one has driven special vehicles as an ambulance or a fire engine car. All experienced drivers have driven motorcycle, van, mobile home and minibuses and one driver has driven all the vehicles listed.

In item 1 were asked drivers to rate their current driving skills, compared to their best period of life, on a scale from 0 to 10. 53.6% of drivers evaluate their skills as 8; 10.7% of them judged it as 7, five drivers have evaluated their skills as 10 (only the male drivers have given this answer, as it is known they tend to overestimate their driving ability), four drivers have evaluated their skill as 9, and only a driver has given a judgment of 3.

In item 1 the average score for the sample amounts to 8.21. All experienced drivers rated their performance as 9.

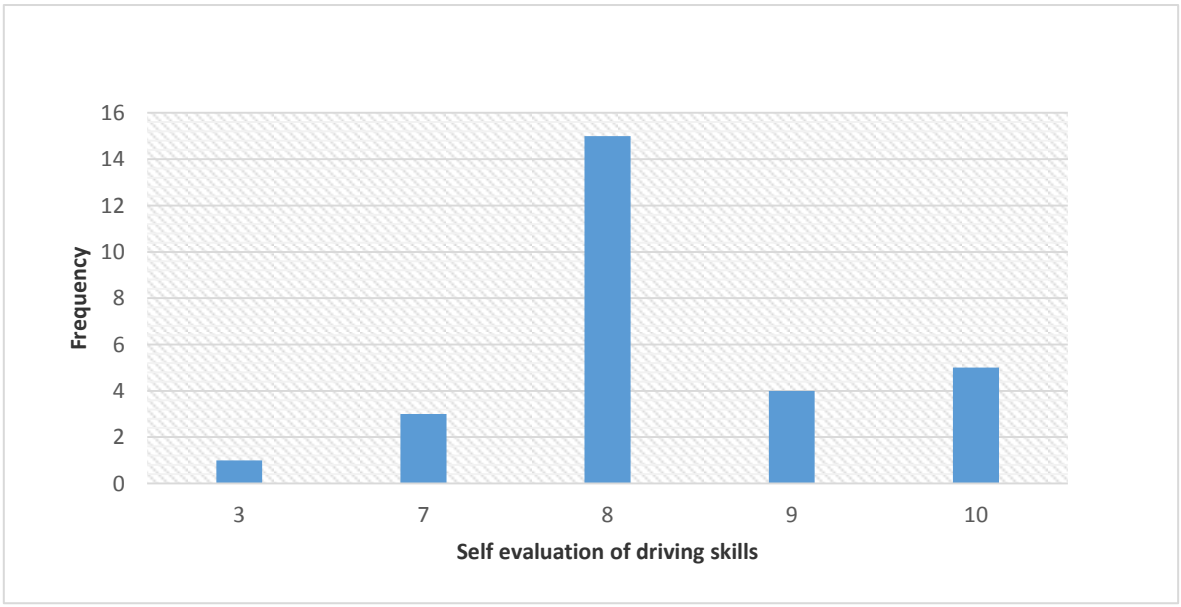

Figure 52 Item 1 self-evaluation of driving ability compared with the best period of life

In item 2 is asked drivers to assess their physical and cognitive skills in relation to driving.

With regard to physical abilities most of the drivers (60.7%) said they have very good physical skills, 28.6% (8 drivers) said they have quite good skills, 10.7% have average physical skills. Two experienced drivers said they have very good physical skills and one has quite good physical abilities.

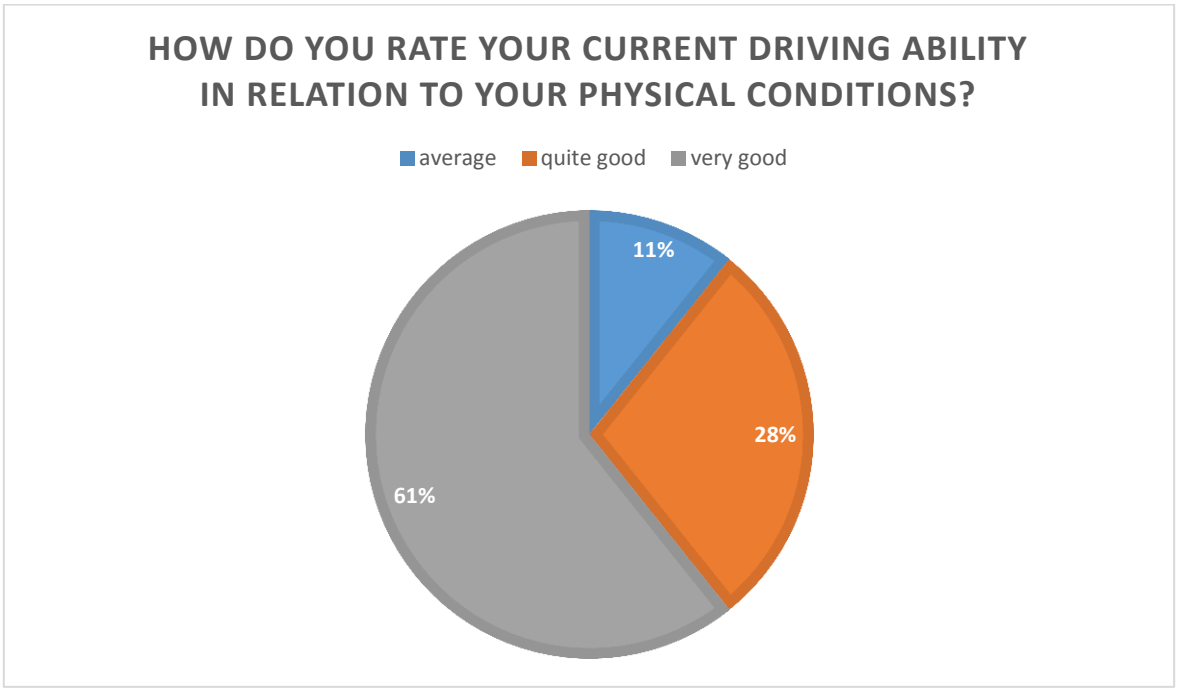

Figure 53 Self-assessment of physical abilities

With regard to cognitive abilities, 60.7% of drivers said they have very good skills, 28.6% (8 drivers) said they have quite good mental skills, one driver considers his cognitive abilities quite poor and another one has very poor mental skills. All experienced drivers reported to have very good cognitive skills.

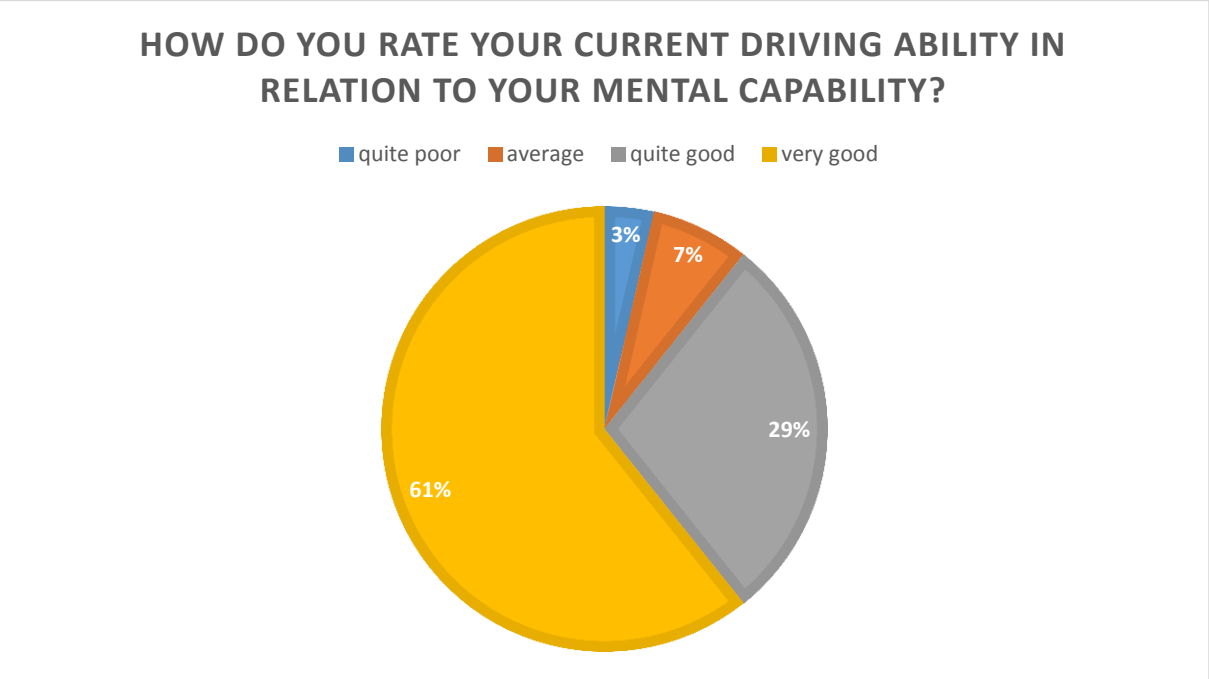

Figure 54 Self-assessment of cognitive abilities

Section 3 refers to the number of diseases diagnosed by a doctor, 20 drivers have musculoskeletal disorders and arthritis is the most common, this disease affects 9 drivers. The maximum number of musculoskeletal disorders in only one driver is 3; drivers have an average of 1.03 diseases in this category.

Cardiovascular diseases have been found in 17 drivers, the maximum number of diseases of this type in only one driver is 3 and the most frequent disease was hypertension; that affects 12 drivers. The average number of cardiovascular diseases in the sample is 0.71.

8 drivers have cognitive or sensory impairments and none driver has more than 2 diseases in this category. Among these, the most frequent was the loss or impairment of hearing, that affects 5 drivers. The average number of cognitive or sensory diseases in the sample is 0.32.

Two drivers have digestive diseases (stones in the liver or gallbladder disorders and gastritis) and one driver has a genitourinary disease (urinary infection).

Only two drivers have skin complains and they have allergies and eczema; two drivers have tumours: one is benign and one is malignant to the prostate.

Four drivers have endocrine and metabolic disorders, the maximum number of diseases in one driver is one, the diseases found in the sample were diabetes, obesity and thyroid disorders.

Respiratory diseases, blood disorders and deficits at birth were not found in any driver interviewed.

A driver among experts does not have any disease, one has a musculoskeletal disease and a cardiac disease, and another has just a musculoskeletal disease. The maximum number of diseases found among experts drivers is 2.

In item 4 is asked drivers to assess their driving skills in relation to their health, 85.7% of drivers have no difficulties due to diseases, four drivers (14.3%) tend to slow down or change their driving style due to illness.

None of them answered: "I feel I am no longer able to drive", "I feel I am only able to drive for short distances," "I Am Able to drive, but it's getting difficult".

The experienced drivers said they have not difficulty driving because of their health conditions.

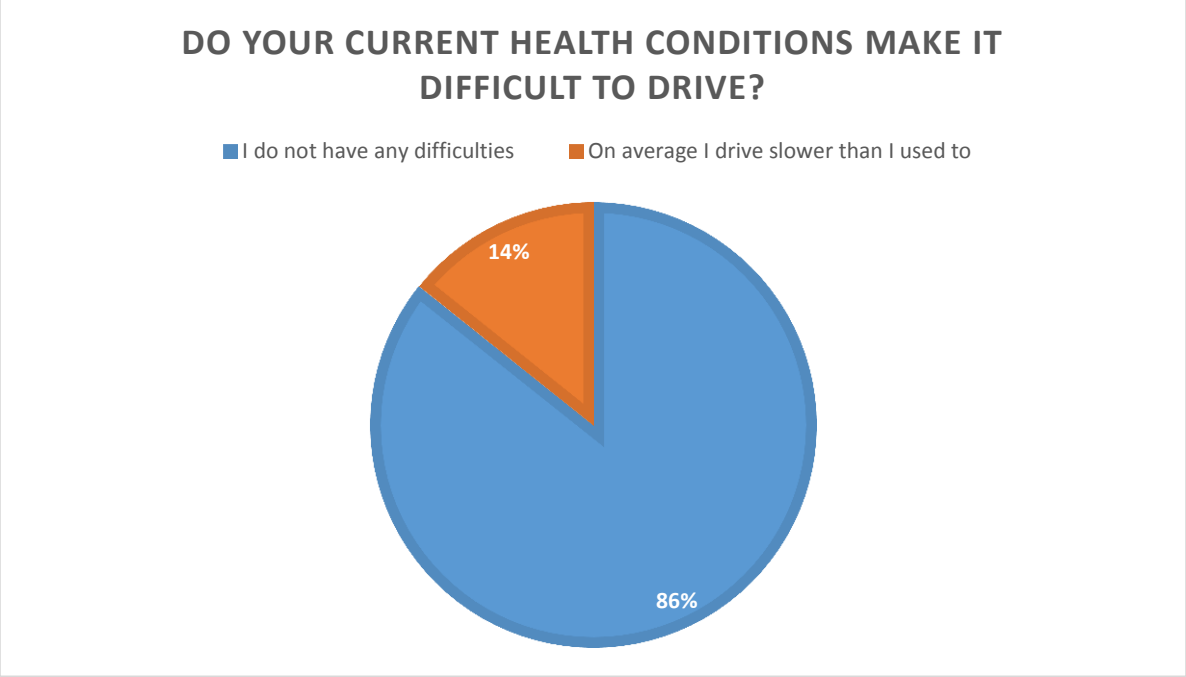

Figure 55 Driving skills in relation to health conditions

In item 5 was asked drivers if they abstained from driving due to health problems in the past year, 92.9% of drivers said that they have never stopped driving because of their health, two drivers have abstained from driving for less than ten days during the last year. None of the experienced drivers stopped driving within the last year.

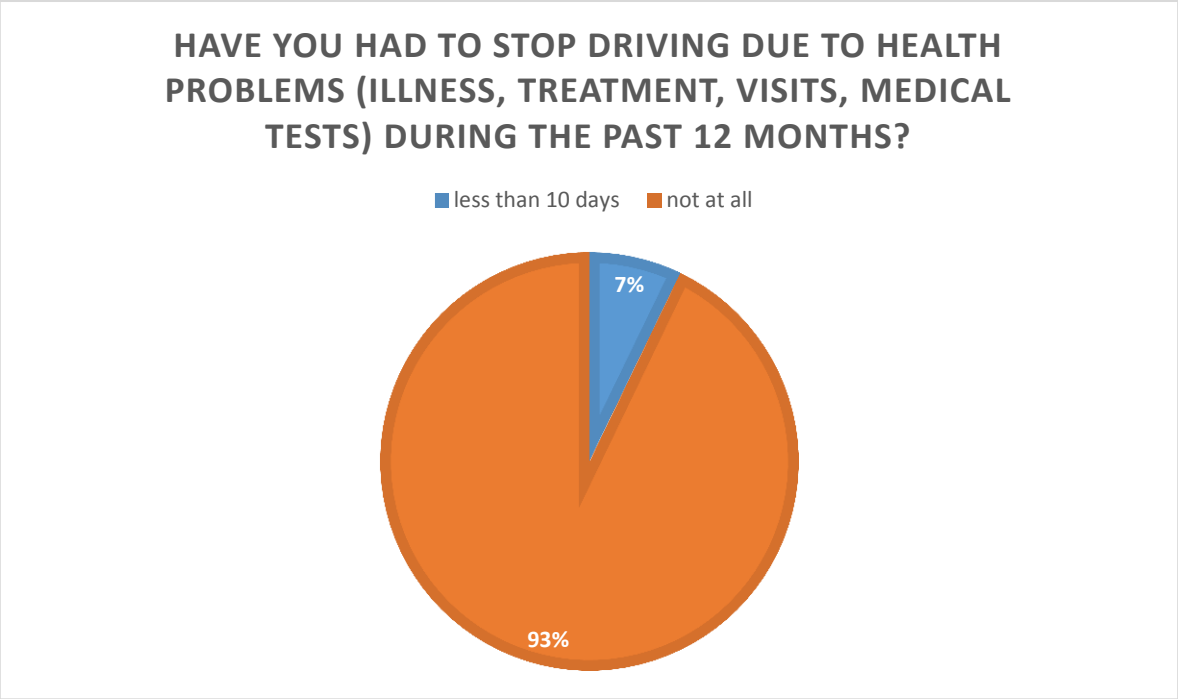

Figure 56 Abstention from driving in the last year due to health problems

In item 6 is asked drivers to predict their driving skills over the next two years, 92.9% of drivers believe that they will certainly be able to drive, and two of them have some doubts about this, in fact they stated that maybe they will be able to drive. All experienced drivers said they definitely they will drive over the next two years.

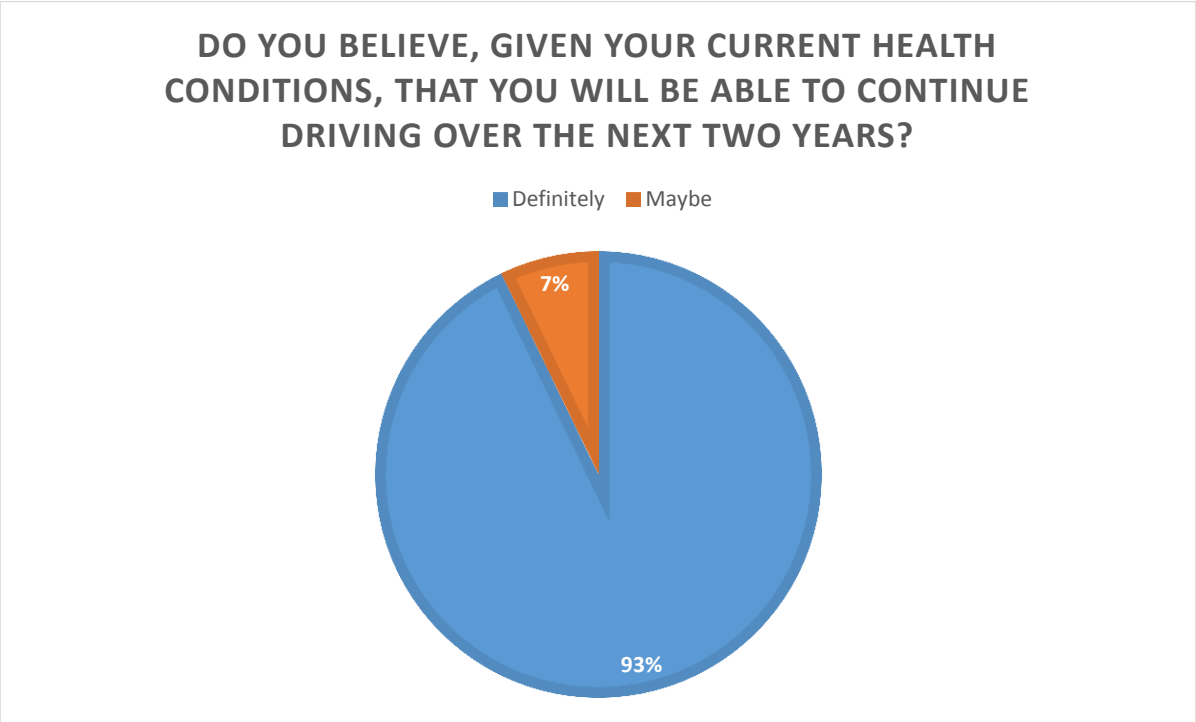

Figure 57 Driving ability in the next two years

In Section 7, related to the driving activity, it was found that the majority of drivers (85.7%) drive their vehicle very often (3 or more times a week), four drivers drive often (once or twice a week). The experienced drivers drive very often (3 or more days a week).

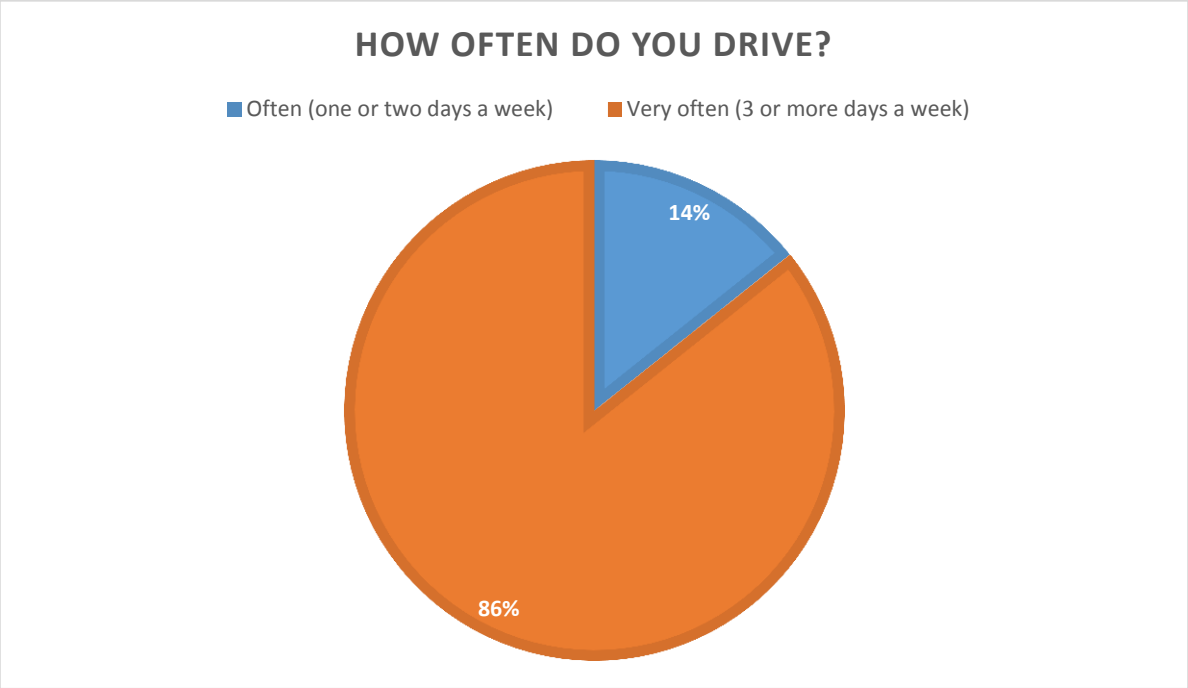

Figure 58 Driving frequency

71.45% of drivers surveyed have committed a driving offense, among them 18 committed it more than one year before the survey, two have committed the offense within the last year. All the drivers have committed the same offence: speeding; usually the speed was 10 miles per hour greater than the speed limit. Only eight drivers have never committed an offense. Two experienced drivers have committed an offense more than one year ago and one has never committed an offense.

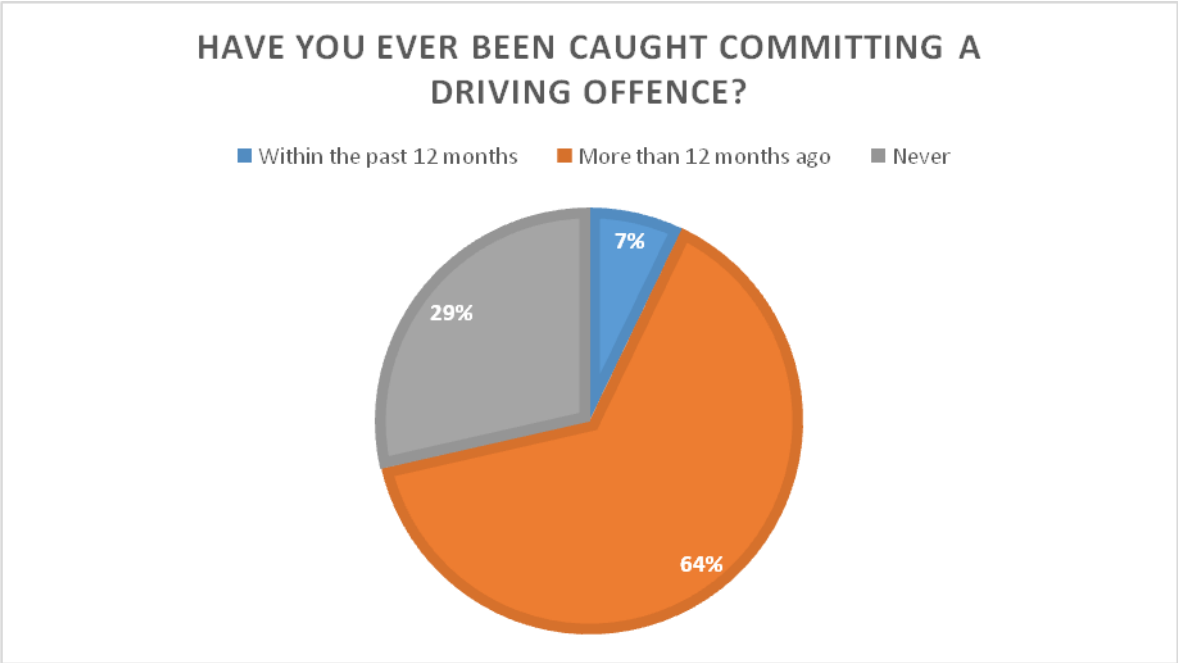

Figure 59 Driving offence

Among the drivers tested the majority (89.3%) has never been involved in an accident in the last five years, the remaining three drivers were involved in accidents that caused damage to vehicles or properties only, but none of them have been involved in accidents with injury to people. Two experienced drivers have never been involved in an accident.

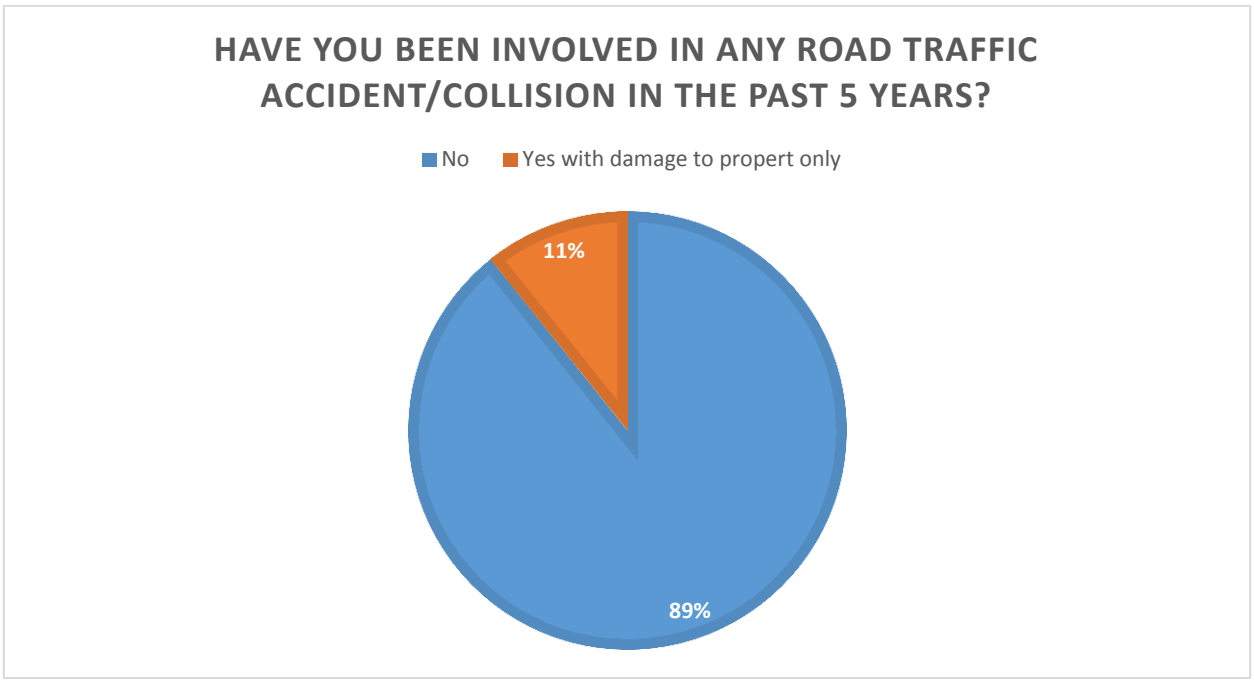

Figure 60 Involvement in accidents

All drivers surveyed said that they use the seat belt and none of them have undergoing any treatments that affect the alertness or the ability to drive.

17.9% of respondents have fallen asleep driving, it never happened for 82.1% of the sample. None of the experienced driver have fallen asleep while driving.

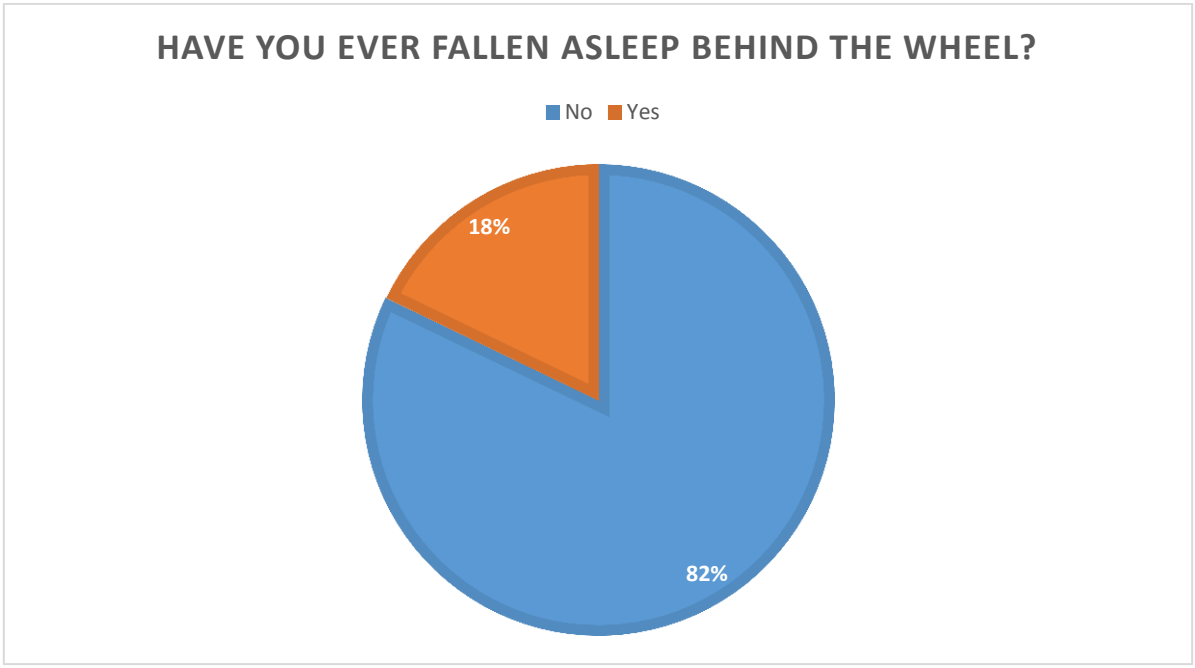

Figure 61 Falling asleep

The vast majority of drivers (96.4%) said that they look the rear view mirror once every few minutes during the drive, only one said that he observe it only during the execution of some specific manoeuvres.

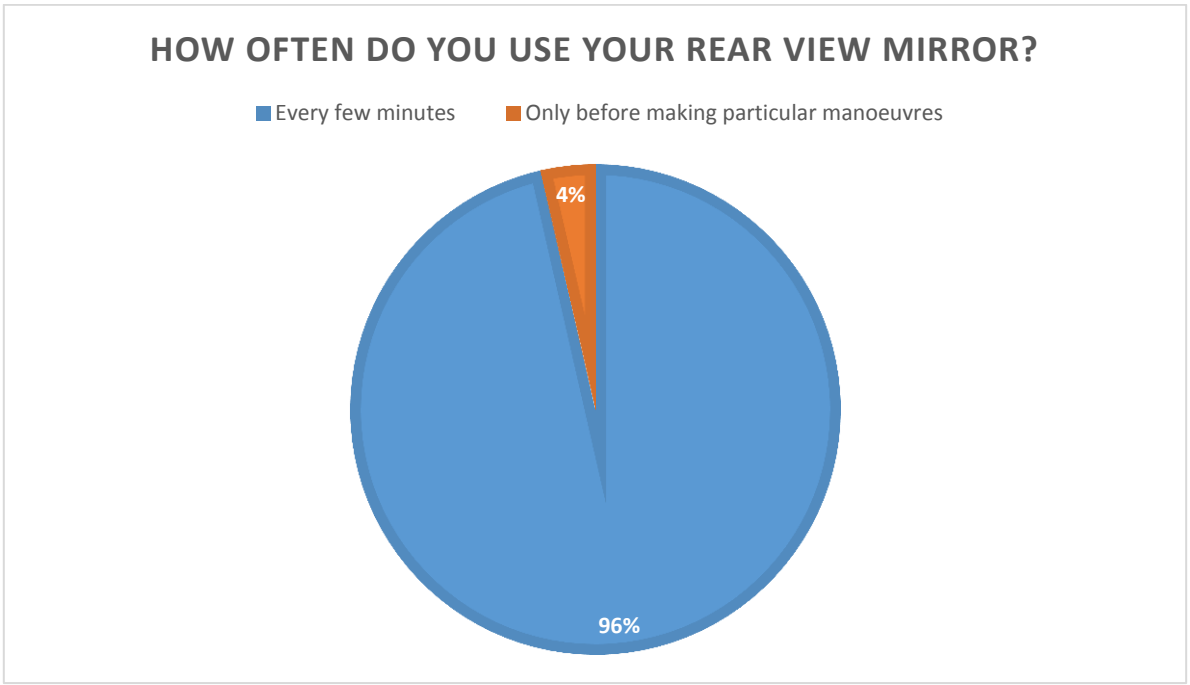

Figure 62 Use the rear view mirror

Among the drivers tested, five said that they often see road signs at the last minute, it never happens to 82.1% of the drivers. None of the experienced drivers see the road signs at the last minute.

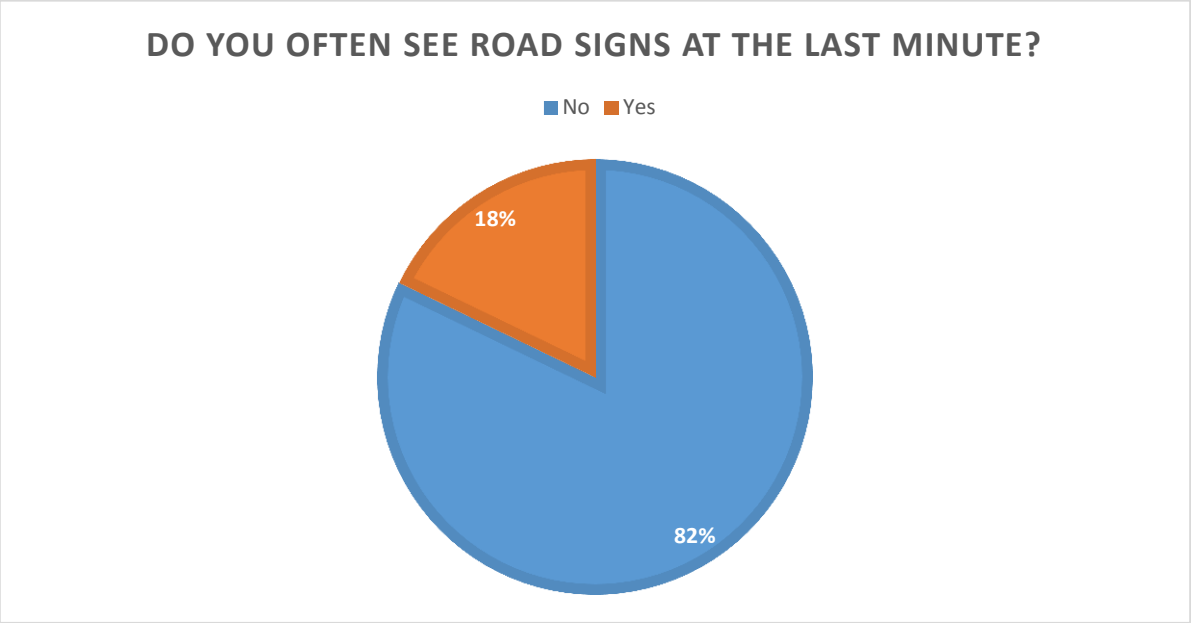

Figure 63 Replies to the question: "Do you often see road signs at the last minute?"

Only one elderly driver has given up driving at night.

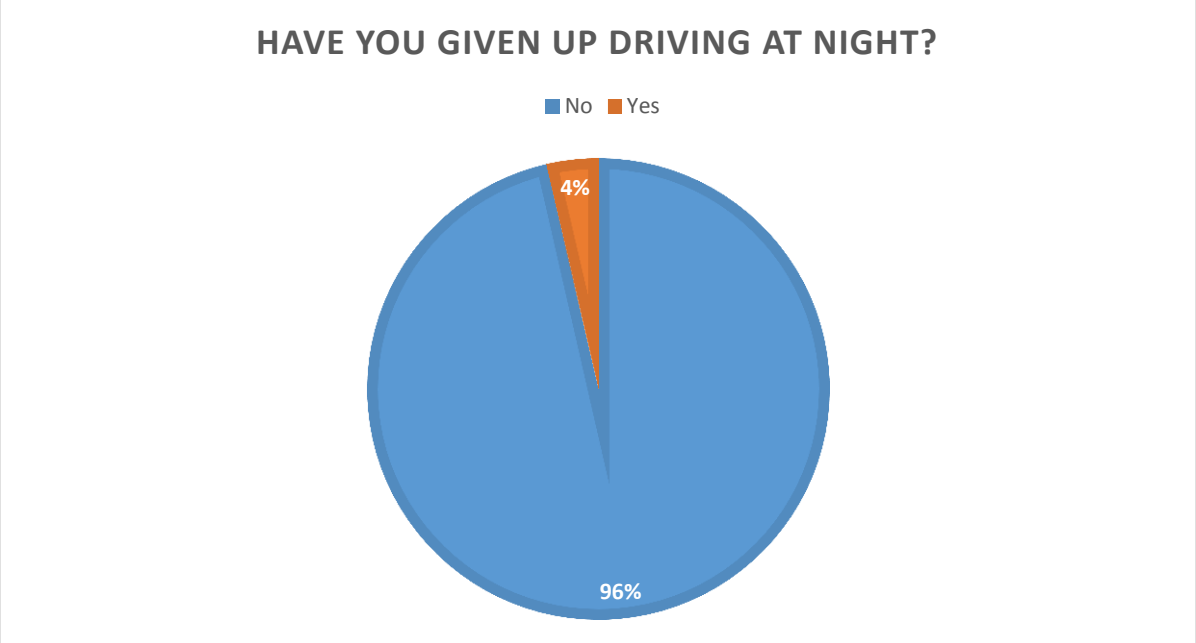

Figure 64 Give up driving at night

64.37% of the drivers are not worried merging into traffic during the night, five drivers are sometimes worried, 2 are often worried and the other three are always worried in such situation. The experienced drivers reported that they are never worried when driving at night.

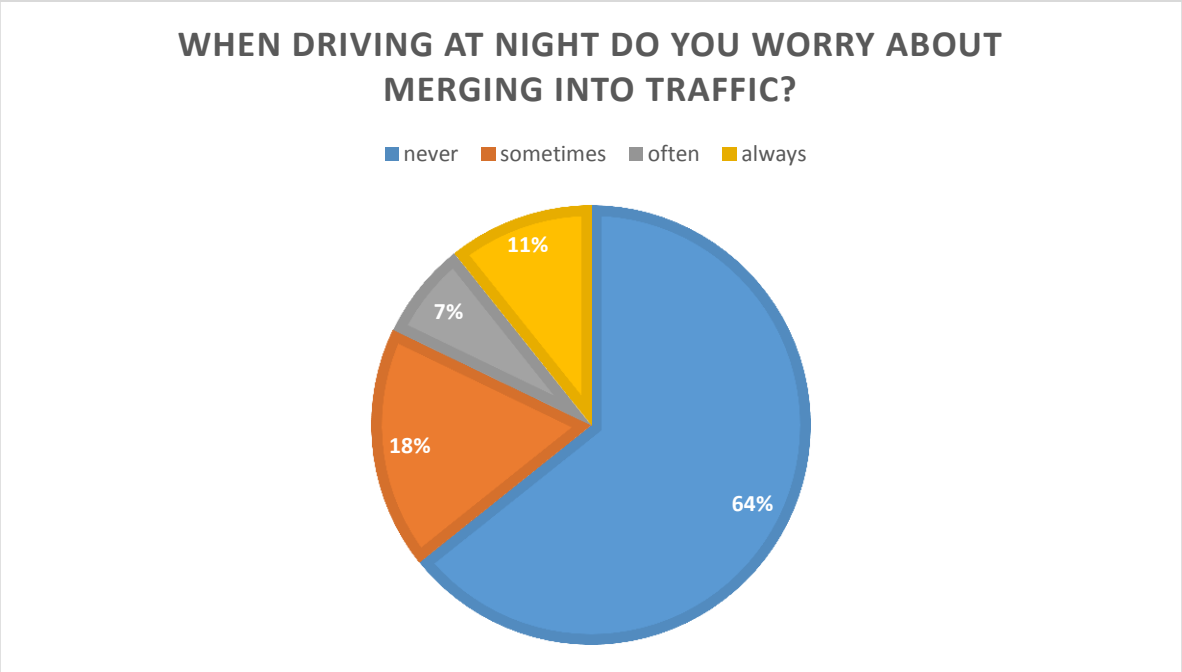

Figure 65 Worry merging into traffic at night

71.4% of drivers is never nervous or stressed driving at night, four drivers are sometimes stressed, one is often nervous driving at night and three are always nervous or stressed when driving at night. The experienced drivers are not nervous or stressed when driving at night.

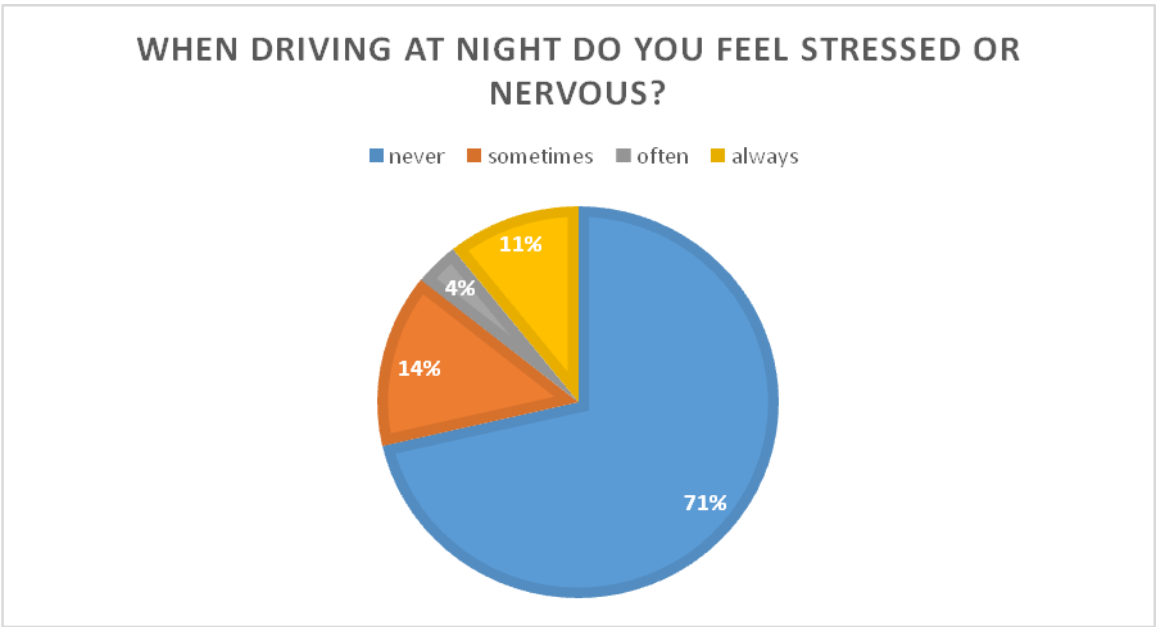

Figure 66 Stress or nervousness in night driving

When driving at night, 53.6% of drivers feel that the road is well lit, 17.9% considers it often well lit, 21.4% feel that the street is only sometimes well lit, two drivers feel that the

road lighting is never enough. Two experienced drivers never feel it poorly lit and one said that the street is sometimes poorly lit.

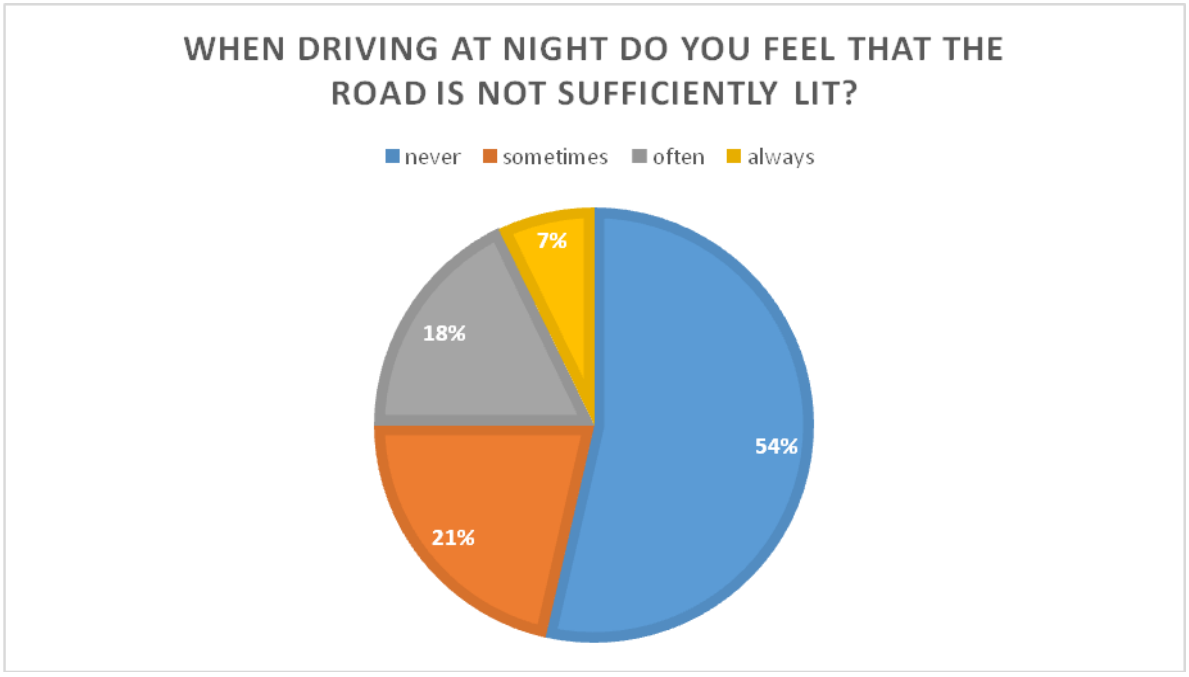

Figure 67 Replies to the question: "When driving at night do you feel that the road is not sufficiently lit?"

It has been asked drivers if they find difficulty in perceiving road marking (guardrail or marking) when driving at night, 60.7% said that they have never been in this condition, nine have sometimes difficulty and two drivers have always difficulty in perceiving road markings at night.

The experienced drivers reported that they never have trouble seeing the road markings.

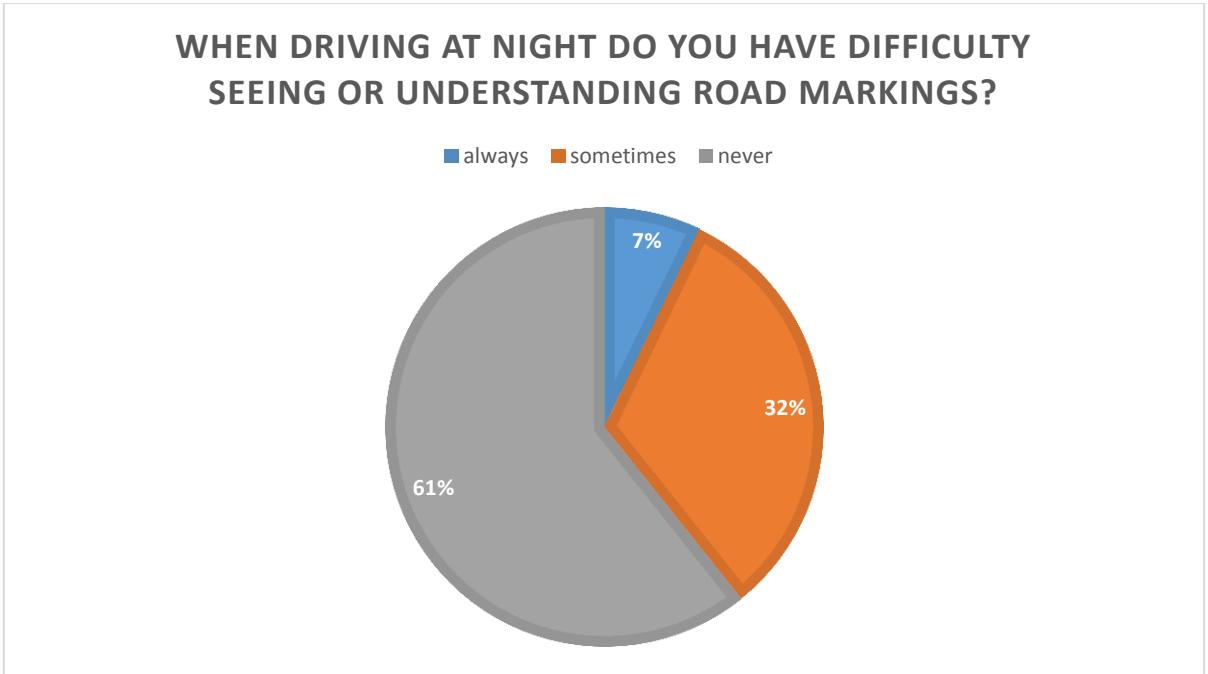

Figure 68 Difficulties to perceive road markings

53.6% of drivers surveyed do not need to slow down to read the signs at night, 32.1% sometimes slow to read the signs, 10.7% of drivers must reduce his speed to read the signs, and only one said that he often have to slow down to read traffic signs.

None experienced driver must slow down to read the signs.

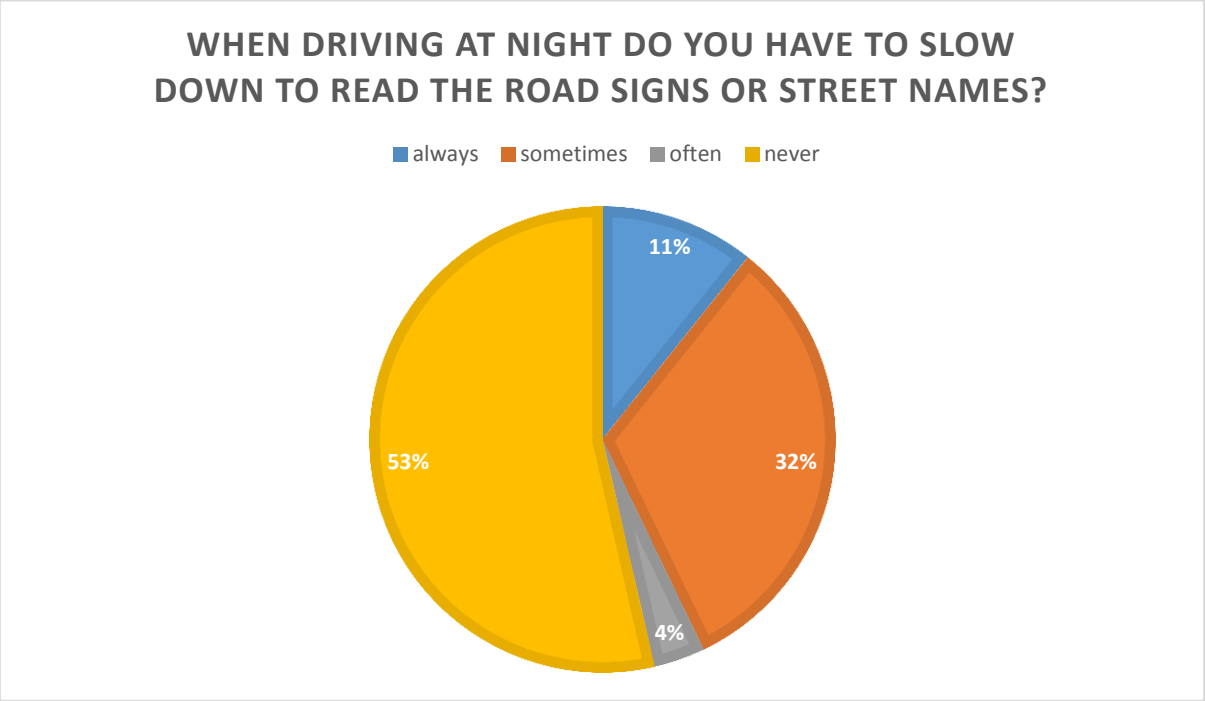

Figure 69 Need to slow down to read the road signs

Using the responses to the questionnaire, the driving ability score was calculated for all drivers included in the survey and in the road test. The following figure shows the evaluations of older drivers (in the graph were not included the experienced drivers, all of them have an excellent driving ability).

Based on this calculation, 50% of the drivers has a good ability to drive, for 36.36% the driving ability is excellent (8 drivers), two drivers have a moderate ability to drive and one has a poor driving ability.

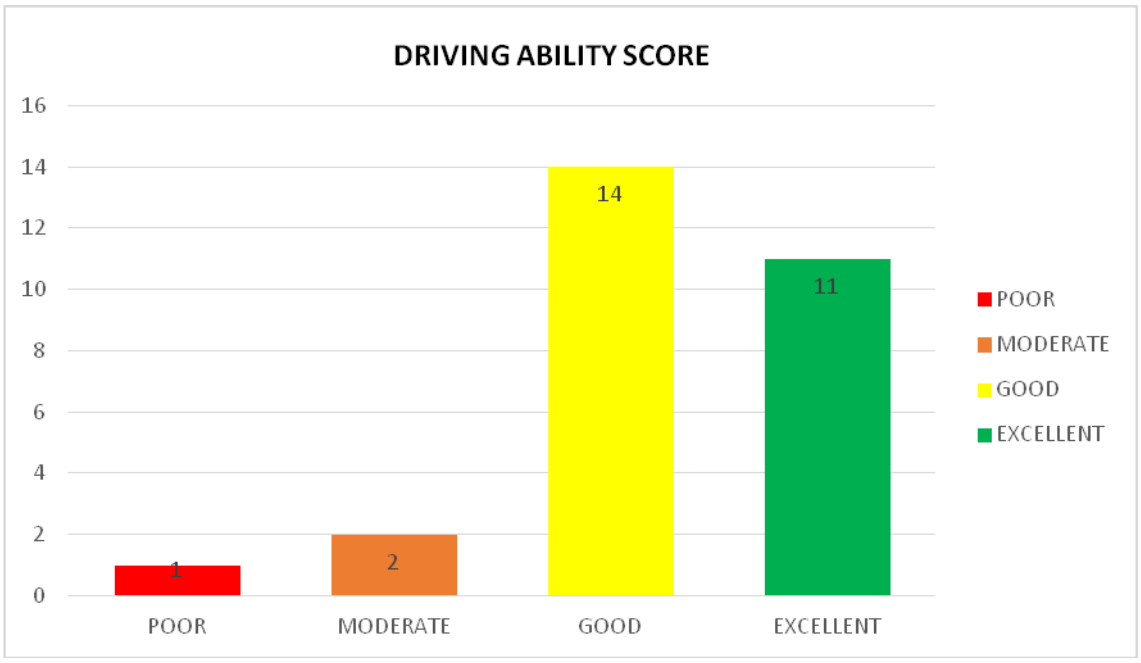

Figure 70 Driving ability scores for drivers tested

Based on responses to the questionnaire all three experienced drivers have excellent driving ability.

5.2.9. Validation of Driving Ability Index with the Kendall tau test

In order to validate the score calculated with the questionnaire, road tests have been performed and on basis of the severity of the errors committed by drivers during the test, their driving ability has been assessed.

The evaluation obtained by drivers with the questionnaire have been compared with that obtained in the road tests through the Kendall tau test. This test proposed by Sir Maurice Kendall (1907-1983) in 1938, allows assessment of two sets of ranks that can be ordinal.

Kendall's tau test type b (τ_b) and c (τ_c) have been applied, they calculate the correlation between two sets of measures, taking into account the effect of tied ranks, and Kendall's tau c test also considers the effect due to the large number of measures.

The null hypothesis of the test is that there is no correlation between the two series of data, differently from usual statistical tests, this test works better with a few objects, also only 4 or 5, and it is not necessary that the data have a Gaussian or Student distribution.

The result of the test is the Kendall's correlation coefficient and it can vary from -1, for an exact inverse correlation, to\ +1, for a positive correlation, for this coefficient a level of significance is measured.

The test has been applied to results obtained for the whole sample (31 drivers) and separately for men (26 drivers) and for women (5 drivers) tested. The Kendall's correlation coefficients and significance levels associated with them are shown in the following table.

Table 10 Kendall's tau correlation coefficients for whole the sample, men and women

	Kendall's tau c Correlation Coefficient	Significance
Sample	0,277	0,044
Man	0,257	0,177
Woman	0,720	0,009

Analyzing the data for the entire sample, the results of the tests in the table show that, the results obtained in the driving tests are poorly correlated with the scores obtained by the questionnaire, because the correlation coefficient amounts to 0.277, and its significance level is high, equal to 95.6%.

Considering the men, the correlation coefficient has a lower value (0.257), this coefficient is not very significant (0.177).

As regards the women included in test, the correlation coefficient is 0.720 and it shows a good level of correlation between driving performance and the result obtained in the questionnaire; the significance level is high (0.009).

This analysis shows that only for women the level of driving ability estimated by the questionnaire reflects their real driving ability.

This result may be due to the greater capacity to self-evaluate that women have, they sometimes tend to underestimate their abilities, in fact they do not renew their licence when they are still able to drive safely, and in the questionnaire there are many questions that require self-evaluation, both in general and in relation to their physical and cognitive abilities.

In order to analyse the differences between the results obtained in the two groups categorized by gender, the correlation between the scores obtained in the road test and in the various items of the questionnaire has been measured. The results are reported in the following table.

Table 11 Results of Kendall's Tau test

	Variables considered	Road test evaluation	Road test evaluation	Road test evaluation	Road test evaluation	Road test evaluation	Road test evaluation	Road test evaluation
		Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7
Sample (31)	Kendall's tau c Correlation Coefficient	0,122	0,169	0,144	0,225	0,108	0,233	-0,140
	Significance	0,411	0,208	0,292	0,152	0,639	0,117	0,287
Men (26)	Kendall's tau c Correlation Coefficient	0,110	0,158	0,158	0,130	-0,071	0,142	-0,580
	Significance	0,527	0,301	0,318	0,394	0,300	0,289	0,701
Women (5)	Kendall's tau c Correlation Coefficient	0,320	0,320	0,120	0,640	0,640	0,640	-0,480
	Significance	0,232	0,500	0,709	0,136	0,136	0,136	0,025

The analysis of the correlation coefficients related to item 1 confirms what previously said: the women have a greater ability to self-assessment (0.320) than for men (0.110), but for both the correlation is low, as well as for the entire sample (0,122). Similar results there have been for the second item which is on self-assessment of physical and mental abilities in relation to driving; correlation coefficient is 0.169 for the whole sample, it is 0,158 for men and it is 0,320 for women.

Item 3 is related to diseases that affect the driver, the correlation is reduced in all cases, but it is slightly higher for men (0.158) than for women (0.120), the value for the entire sample is 0.144.

Item 4 estimates the reduction of driving ability due to health conditions, this variable is correlated with the assessment obtained in the road test for women (0.64), but not for men (0,130) and for the entire sample (0.225). This shows that women have a greater ability to self-evaluate the reduction of their driving skills on the basis of diseases. The fifth item is relative to abstention from driving for disease in the last year, this variable is related to the real driving skills for women (0,640) and for men has a low negative value (-0.071). For the whole sample the coefficient is 0.108.

Item 6 is about the prediction of the driving ability in the next two years, even in this case, the variable is correlated for women (0,640) and not for men (0.142) and for the entire sample (0,233). The results of these tests show a greater capacity to self-assess their future driving skills for woman, compared to their peers of the other gender.

The item 7, which is about the driving activity, is negatively correlated with the ability to driving, for men (-0.580) was more closely related than for women (-0.480), the value obtained for the whole sample is (-0.140).

5.2.10. Influence of the familiarity with the route on driving performance

During the survey were asked to drivers what is their level of familiarity with the areas in which the tests were performed which are: Metrocentre, Dunston and Whickham. Drivers have expressed a level of familiarity by a judgment that ranges from 1 (first time in the area) to 5 (very familiar) for the three areas crossed.

In all three cases the judgment expressed varied between 1 and 5, the average level of familiarity is similar for the three areas, it amounts to 3.03 (SD = 1.33) for Metrocentre, 2.71 (SD = 1.3) for Dunston and 2.74 (SD = 1.34) for Whickham.

To check if driving performance were influenced by the level of familiarity with the area, a Kendall'tau test was performed. The test results are shown in the following table.

Table 12 Results of Kendall's Tau test

	Variables considered	Road test evaluation	Road test evaluation	Road test evaluation
		Metrocentre	Dunston	Whickham
Sample (31)	Kendall's tau c Correlation Coefficient	0,253	0,144	0,164
	Significance	0,26	0,222	0,191
Men (26)	Kendall's tau c Correlation Coefficient	0,225	0,103	0,138
	Significance	0,092	0,436	0,332
Women (5)	Kendall's tau c Correlation Coefficient	0,24	0,24	0,24
	Significance	0,443	0,543	0,443

Test results show that in all three cases driving performance are not affected by the level of familiarity with the area, in fact considering the entire sample, the correlation coefficient between the driving performance and the level of familiarity with 'Metrocentre

area is 0.253, with Dunston is 0.144 and for Whickham is 0.164. Even if we consider separately the two genders, the result is the same, in fact the correlation coefficient Kendall is always smaller than 0.24. For this it can be assumed that the results obtained in the road tests are not affected by familiarity with the areas crossed during testing.

6. EXPERIMENT 2: DRIVING SIMULATOR TESTS

6.1.Validation of the questionnaire through driving simulator tests

In order to assess the ability of Driving Ability index to evaluate driving ability in older drivers, the results obtained by the questionnaire were compared to the results obtained in the driving simulator.

These tests were conducted as part of the SIDE project (Social Inclusion through the Digital Economy), by five researchers, in the group Torg from Newcastle University and a researcher of Monash University (Australia).

In this study the effect of the device "Intelligent Speed Adaptation" (ISA) for controlling the driving speed of the vehicle, for elderly drivers, was tested (Guo, 2014). The elements considered for the evaluation of the driving performance were the ability to control the speed and to maintain the correct position into the lane.

In this study the performance of the drivers have been evaluated, without ISA device for controlling the speed and with the device with three different levels of action, but for the purposes of this thesis only the performance without the ISA device have been considered, so in normal driving conditions.

6.2.Driving simulator

The driving simulator used have been developed for research purposes by the group Torg from Newcastle University. The simulator consists of a cabin made of aluminium, equipped with five LCD displays with high resolution, they are large 50 inch and they are placed in a circular way around the driving position. In addition, the typical car noise is reproduced, so as to create an immersive driving environment.

The simulator is equipped with control devices typical of a car, as the steering wheel with force feedback, the hand brake lever and there are the pedals of the clutch, accelerator and brake; it is equipped with adjustable seat and safety belt.

Through the three screens placed in front position the three mirrors: left, right and rear view mirror are displayed. The simulator was set to collect data every 0,1 s.

Figure 71 Driving simulator

Figure 72 Cockpit of the driving simulator

6.3.Scenario used

Through the simulator the circular path represented in the following figure has been displayed to drivers, the path consist of seven road segment of different length, for a total length of 2.35 miles (3.78 km).

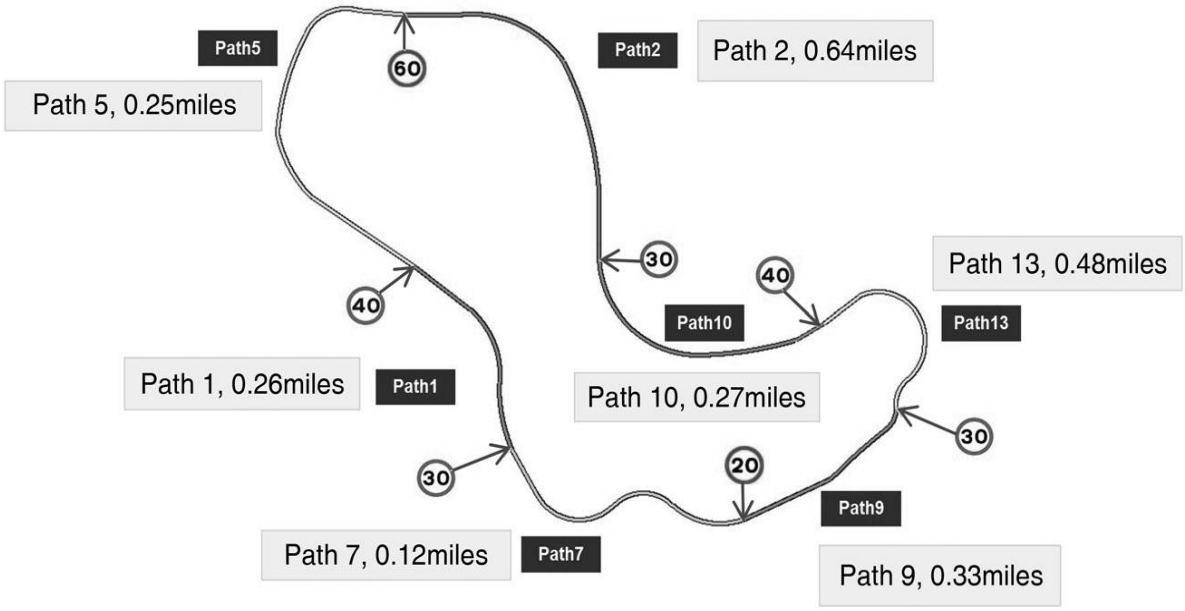

Figure 73 Circular path displayed during the test – Source: Guo,2014

6.4.Sending the questionnaires

In order to send and fill in the questionnaire DAI easily, this has been built by a software, which made it possible to send them via e-mail. The questionnaire was sent to 16 drivers who were tested with driving simulator (5 under the age of 60 years and 13 older) among these 7 drivers have completed the questionnaire (2 under the age of 60 years and 5 older). Five elderly drivers included in the road tests have been tested with the simulator and they have completed the questionnaire during the road test.

So twelve drivers (2 under the age of 60 years and 10 older) have been included in this step of the study.

6.5.The sample tested

To be eligible for the study, the participants were required to be experienced drivers, holding a license for at least 10 years.

Tested sample includes seven men and three women over the age of 60 years and two young drivers: a man and a woman.

The average age found in the sample is 71.7 years (SD = 7.15), and it varies from a minimum of 61 to a maximum of 86 years.

6.6.Data obtained through the questionnaire DAI: Frequency Analysis

In this analysis only drivers over sixty years have been included.

The majority of drivers included in the tests (6 drivers) drive very often (three or more times a week) and four drivers drive often, one or two times a week. Five drivers drive sometimes with other people; three drivers travel with other people most of the time and two drivers drive occasionally with other people.

All drivers usually are drivers and not passengers when they travel by car. Only one driver is still working and nine are retired.

Regarding the education of drivers, only one has not qualification, one has achieved GCSE / O level and equivalents, three have achieved A levels and equivalents and five have achieved a university degree.

None of the drivers was smoking at the time of the survey, eight have never smoked and two are ex smokers.

With regard to alcohol consumption, four drivers drink monthly or less, three drink 2 or 3 times a week, two drivers drink 4 or more times a month and one driver drinks from 2 to 4 times a month; seven drivers consume 1 or 2 units of alcohol usually when they drink, one driver drinks 3 or 4 units, one driver drinks 5 or 6 units and another driver drinks from 7 to 9 units.

Drivers have expressed the satisfaction level on the quality of their sleep with a scale that ranges from 1 to 5. Three drivers are very satisfied and they evaluated their sleep as 5, two have reported a satisfaction level of 4, three have reported a satisfaction level of 3, and one driver has declared a satisfaction level of 2 and one driver assessed the satisfaction level as 1. The average level in the sample amounts to 3.5.

The drivers drive on average from 49.6 years (SD = 8.63) and the years of driving range from a minimum of 31 to a maximum of 62 years. Eight of them have never stopped driving for more than three months since they obtained the licence and one driver has stopped driving for 15 weeks due to health problems (broken femur) and one driver stopped to drive for one year for volunteering.

The majority of drivers (7 drivers) travel daily from 5 to 25 miles, two travel less than 5 miles and one driver travels more than 25 miles.

Three drivers travel annually from 2001 to 5000 miles, four drivers travel from 5001 to 8000 miles and three driver travel from 8001 to 10,000 miles per year. None of them travels less than 2000 miles or more than 10000 per year.

46.5% of the travel take place in urban areas and 43.05% take place in suburban area.

The vehicles used by drivers have on average 5.4 years (SD = 4.12) and the older vehicle dates back to 2001 and the most recent has been purchased in this year.

The drivers drive mostly cars with an engine of small size, four of them have a vehicle with an engine sized between 1.0 and 1.3 L; three drivers drive vehicles with a cylinder capacity lower than 1.0 L, two drivers drive a vehicle with an engine sized between 1.7 and 1.9 L, and only one driver drive a vehicle with the engine bigger than 2.0 L.

Only one of the drivers tested achieved the qualification "Advanced Motorist test". 7 of the drivers surveyed have driven a motorcycle; 9 have driven a van, a mobile home or a minibus, two have driven a lorry or a bus, 7 drivers have driven a sports car and only one has driven a special vehicle like an ambulance or fire engine car.

In item 1 drivers had to rate their driving ability compared to their best time of life, the average value for this answer was 7.83 (SD = 0.83).

Five drivers assessed their skills as 8, two drivers evaluated their skills as 7 and other two drivers assessed their skills as 9, but only one driver has assessed its ability as 6.

The great majority of drivers assessed their physical condition in relation to driving as quite good (5 drivers), three judged their abilities as very good and two have rated them as medium.

Regarding mental abilities required for driving, five drivers have assessed them as quite good four drivers evaluated their skills as very good and only one driver has average mental skills.

Item 3 relative to medical conditions showed that 8 drivers have musculoskeletal diseases, the driver who has the most number of diseases of this type has 4 diseases and the most common disease in this category is arthritis that affects two drivers.

Three drivers have cardiovascular diseases and each of them has only one pathology, the most frequent is hypertension that affects two drivers.

None driver have respiratory diseases, skin complains, blood problems or other illnesses.

Only one driver has sensory impairments at the sight.

Two drivers have digestive problems and they have gastric or duodenal ulcer, gallstones or liver and gastritis or duodenitis, irritable bowel syndrome.

Two drivers have genitourinary problems like inflammation of the ovaries and urinary infections.

A driver has a benign tumour. Two drivers have endocrine or metabolic diseases like diabetes and thyroid problems.

None of the young drivers tested has health problems.

With respect to item 4, the majority of drivers say they never have any trouble driving due to their health, only one driver need to slow down and change his driving style because of health problems.

None of the drivers surveyed in the last year has given up driving for health reasons, and all drivers predict that they will surely continue to drive in the next two years.

Six drivers drive their vehicle very often (three or more times a week), four drivers drive often (once or twice a week).

The vast majority of drivers have committed a driving offense (9 out of 10 drivers), eight of them have committed an offence more than one year ago; one driver committed an offence within the last 12 months and one driver has never committed an offense.

Nine drivers have never been involved in a road accident in the last five years and one driver has been involved in an accident, which caused damage to property only.

All drivers stated that they always wear the seat belt while driving and none driver assumed therapies that affect the alertness.

Among the drivers tested four have fallen asleep while driving. All drivers surveyed said they use the rear view mirror every few minutes. Only two drivers have said that they often see road signs at the last minute. None driver has given up driving at night.

With regard to driving at night, five drivers are not worried when merging into traffic, four drivers are sometimes worried; only one is often worried when merging into traffic.

Seven of the drivers surveyed said that they are never nervous or stressed for night driving, three drivers are sometimes nervous.

As regards the question "When driving at night do you feel that the road in not sufficiently lit?", five drivers said that they "never" feel the street poorly lit; three drivers

answered "sometimes," one driver said "often" and one driver said that he "always " feels the street not sufficiently lit.

Six drivers have no difficulty to perceive the road markings at night and four drivers often experience difficulties in perceiving road markings.

Drivers in prevalence (5 drivers) do not need to slow down to read the street names or road signs during the night, four drivers sometimes have to slow down and one driver always needs to slow down to read street names.

6.7.Calculation of the Driving Ability Index for drivers tested in simulator

Based on the responses to the questionnaire, the score for each driver was calculated and the classification in the DAI categories has been obtained.

The results showed that nine drivers have good driving skills and three drivers have excellent driving skills. These results are showed in the figure below.

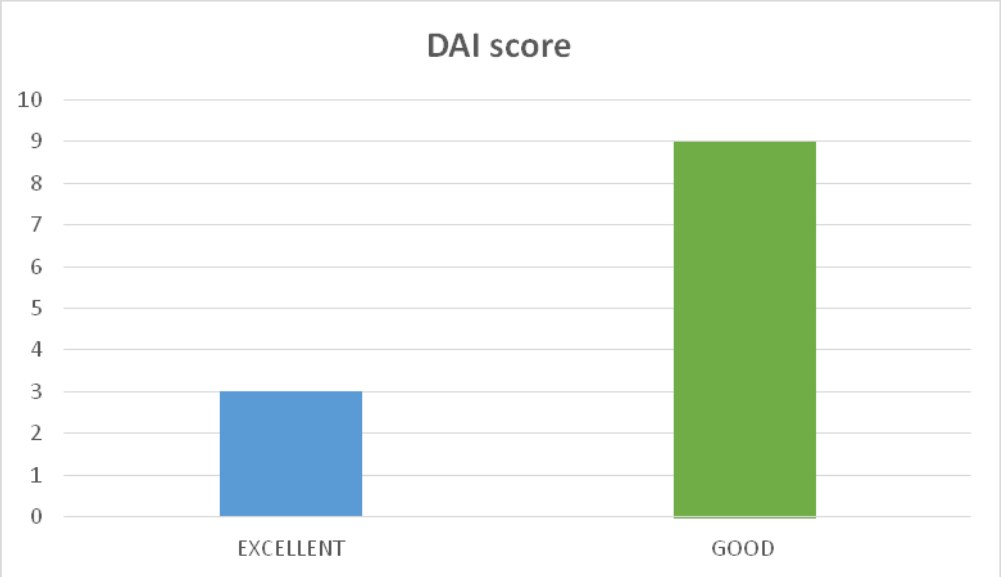

Figure 74 DAI score for the drivers tested in the driving simulator

6.8.Output data of the driving simulator

In the study performed by the group TORG with the driving simulator, the performance of drivers have been evaluated considering their ability to respect the speed limit and their ability to maintain the correct position within the lane.

In order to evaluate lane - keeping performance, the position of the car inside the lane has been considered, a ‘0’ value of the lane position represents the centre of the lane. A

negative/positive value indicates that the car was on the left/right side of the central line, respectively. The lane width was 3 m and the vehicle width was 1.6 m. Hence, any value larger than 0.7 (1.5–0.8) or smaller than −0.7 (−1.5 + 0.8) means that the vehicle was either over the lane or on the pavement.

To translate the lane-position data into lane-keeping performance a scale of 1– 4 was applied for the ranking with '1' being the poorest performance and '4' being the best performance.

To translate the speed data into performance, the same ranking method was applied; each speed - data greater than 10% of the speed limit has been considered speeding.

Also in this case, on basis of the speed, the scale of 1–4 was adopted for ranking with '1' being the poorest performance and '4' being the best performance.

The results obtained by the drivers are shown in the following table.

Table 13 Output data of the driving simulator

Driver ID Simulator test	Lane	Speed	Mean driving performances in simulator test
1	4	2	3,00
2	2	4	3,00
3	3	1	2,00
4	3	1	2,00
5	1	1	1,00
6	3	3	3,00
7	3	1	2,00
8	4	3	3,50
9	3	1	2,00
10	1	1	1,00
11	1	2	1,50
12	2	1	1,50

6.9.Comparison of results obtained with questionnaires and in the simulator

Table 14 Results of Kendall's Tau b test

	Variables considered	Driving ability score (questionnaire)	Driving ability score (questionnaire)-	Driving ability score (questionnaire)
		Lane	**Speed**	**Driving simulator performances**
Sample (12)	Kendall's tau b Correlation Coefficient	0,000	0,054	-0,048
	Significance	0,500	0,425	0,431
Men (8)	Kendall's tau b Correlation Coefficient	-0,301	-0,408	-0,462
	Significance	0,194	0,126	0,087
Women (4)	Kendall's tau b Correlation Coefficient	0,577	0,894	1.000
	Significance	0,159	0,051	0,00

The test results shown in the table above reveals that by analysing the data for the entire sample, the average result obtained in the simulator test is poorly correlated with the score obtained through the questionnaire and the negative sign indicates that they have opposite trends, the correlation coefficient amounts to -0.048 and its significance level is low (0.431). The DAI score is not correlated with the ability to maintain the position within the lane (the coefficient is 0) and with the ability to control the speed (the coefficient is 0.054), both tests are not significant (the significance is 0.500 and 0.425 respectively).

Considering only the men, the correlation coefficient between the performances in the simulator and the DAI score is lower than for the whole sample and it amounts to

-0.462, this coefficient is not significant level (0.087).

Similar results were obtained comparing the ability to maintain the position in the lane, and the ability to control the speed (-0.301 and -0.408); also in these tests the level of significance is not good.

For the women included in the tests, the DAI score and the overall score obtained in the simulator have the same trend, as the coefficient shows, that amounts to 1 and the test

result is very significant. Also the coefficient of 0.894 shows a good level of correlation between the ability to control the speed and the result obtained in the questionnaire and the coefficient is significant (0.051).

There is high correlation between the ability to control the position in the lane and the DAI score (coefficient of 0.577) and the test is not particularly significant.

As in the previous experiment, these analyses showed that only for women the driving ability estimated by the questionnaire reflects their driving skills measured by the driving simulator.

To know the reason for this difference between the two genders, the correlation between the different items and the driving performance measured with the simulator has been evaluated through Kendall's tau b test. The test results are shown in the following table.

Table 15 Results of Kendall's Tau b test

		Variables considered	Lane	Speed	Driving simulator performances
Item 1	Sample	Kendall's tau b Correlation Coefficient	0,726	0,326	0,72
		Significance	0,00	0,07	0,00
	Men	Kendall's tau b Correlation Coefficient	0,759	0,229	0,728
		Significance	0,00	0,433	0,00
	Women	Kendall's tau b Correlation Coefficient	0,577	0,894	1
		Significance	0,157	0	0,00
Item 2	Sample	Kendall's tau b Correlation Coefficient	0,397	0,045	0,281
		Significance	0.088	0,852	0,292
	Men	Kendall's tau b Correlation Coefficient	0,295	-0,167	0,141
		Significance	0,221	0,552	0,657
	Women	Kendall's tau b Correlation Coefficient	0,33	0,516	0,577
		Significance	0,317	0,157	0,157
Item 3	Sample	Kendall's tau b Correlation Coefficient	-0,184	-0,24	-0,266
		Significance	0,26	0,346	0,087

	Men	Kendall's tau b Correlation Coefficient	-0,286	-0,416	-0,431
		Significance	0,149	0,142	0,005
	Women	Kendall's tau b Correlation Coefficient	-0,236	0,183	0
		Significance	0,564	0,739	1
Item 4	Sample	Kendall's tau b Correlation Coefficient	-0,422	-0,368	-0,447
		Significance	0,253	0,27	0,251
	Men	Kendall's tau b Correlation Coefficient	-0,552	-0,445	-0,529
		Significance	0,212	0,258	0,212
	Women	Kendall's tau b Correlation Coefficient	*	*	*
		Significance	*	*	*
Item 5	Sample	Kendall's tau b Correlation Coefficient	-0,127	0,23	0,000
		Significance	0,405	0,283	1,000
	Men	Kendall's tau b Correlation Coefficient	*	*	*
		Significance	*	*	*
	Women	Kendall's tau b Correlation Coefficient	0,333	0,516	0,577
		Significance	0,317	0,157	0,157
Item 6	Sample	Kendall's tau b Correlation Coefficient	*	*	*
		Significance	*	*	*
	Men	Kendall's tau b Correlation Coefficient	*	*	*
		Significance	*	*	*
	Women	Kendall's tau b Correlation Coefficient	*	*	*
		Significance	*	*	*
Item 7	Sample	Kendall's tau b Correlation Coefficient	0,416	-0,31	0,222
		Significance	0,07	0,13	0,519

	Men	Kendall's tau b Correlation Coefficient	0,765	-0,27	0,367
		Significance	0	0,281	0,046
	Women	Kendall's tau b Correlation Coefficient	-0,333	-0,516	-0,577
		Significance	0,317	0,13	0,157

* It was not possible to calculate the test because all respondents gave the same answer.

The first item is about the self-assessment of driving ability compared with the best period of life. For men this is well correlated with the ability to maintain the position in the lane (0.759) but not with the ability to control the vehicle's speed (0.229), it is however correlated with the overall score obtained in the simulator (speed and lane) (0,728), instead for women, the ability to maintain the position in the lane (0.577) is more related with item 1 than the ability to control the speed (0,894), and the correlation is perfect (coefficient is 1) with the overall scores obtained on the simulator.

The second item refers to self-assessment of physical and cognitive abilities, this is poorly correlated with the ability to maintain the position in the lane for both men (0,295) and women (0.33). Item 2 is poorly correlated with the ability to maintain the speed for women (0,516) and it has a negative correlation for men (-0, 167), considering the overall score obtained on the simulator, it has a higher correlation for women (0.577) than for men (0,141).

Item 3 is about the diseases that affect the driver, this is negatively correlated with the ability to maintain the position in the lane for both men (-0.286) and women (-0.236). Item 3 is negatively correlated with the ability to control the speed for men (-0.416) and it is positive but poorly correlated (0.183) for women.

The fourth item is relative to the reduction in the driving ability due to health conditions, this has a negative correlation with the ability to maintain position in the lane (-0.552) and with the ability to control the speed (-0.445) for men, however it was not possible to estimate the value for women because all four women involved in the survey gave the same answer.

Item 5 is relative to abstain from driving due to diseases, for women this is poorly correlated with the ability to maintain the position in the lane (0,333) and to control the speed (0.516), however it was not possible to calculate correlation coefficients for men.

The item 7 is relative to the driving activity, for men, this is correlated with the ability to maintain the position in the lane (0.765) but not with the ability to control the speed (-0.27), instead for women is negatively correlated with both performances measured in the simulator.

6.10. Comparison between driving ability on the road and on the simulator

In order to verify the realism of the simulator and the ability to reproduce the same conditions as the real driving; the results obtained with the driving simulator and in tests on the road were compared, for five drivers who have been tested in both tests, through the Kendall's tau b test.

The following table shows the results obtained through the Kendall's tau test from the comparison between the performance driving on the road and the results in the simulator with regard to the ability to control the speed, to maintain the correct position of the vehicle within the lane and with the overall score in the simulator (average of the two previous scores).

Table 16 Results of Kendall's Tau b test

Variables considered	Driving ability on road test - Lane	Driving ability on road test - Speed	Driving ability on road test - Driving simulator performances
Kendall's tau b Correlation Coefficient	0,354	0,354	0,471
Significance	0,210	.210	0,141

The test results show that the abilities to control the speed and to maintain the lane (measured in the simulator) are not related with the driving performance measured in the on road tests, because the correlation coefficients amount to 0.354 and the significance level is 79% (0.210).

Similar results were obtained comparing the overall score in the simulator with the score obtained in road tests, in fact, the Kendall's tau correlation coefficient is 0.471 and the significance level is 85.9%.

This may be because in the tests in the simulator only two aspects of driving (keep the position in the lane and control the speed) were considered. For this reason tests done in the simulator, were not considered in the subsequent phases of the research.

7. DATA ANALYSIS

7.1. Variables

With the aim to verify the significance of the variables considered in the questionnaire on the ability to drive and to estimate the weight of each of them, linear regression techniques have been used.

In the questionnaire, 50 variables were considered, some of which were not included in the analysis because all drivers have given the same answer, the questions are: "Are you usually the main driver or the passenger when travelling with others?" in which all drivers answered "Main driver".

The questions related to diseases affecting drivers are 11 but the variables "respiratory diseases", "blood diseases" and "other diseases diagnosed by a doctor," have not been included in the analysis, and it was introduced the variable “total number of diseases”.

Also the question “How often do you wear your seat belt when driving?” has not been considered because all drivers answered "always", the question “Are you undergoing treatment that affects your alertness?”, has not been considered because none driver takes treatments that affect the ability to drive, as well as the question “How often do you use your rear view mirror?” because all or drivers answered "every few minutes" and only one driver responded "Only before making Particular manoeuvres", instead by analysing the data obtained from the eye tracker it was found that some drivers do not use mirrors, although they have said they always use them.

Some variables have been treated as continuous variables, such as: “Age”,” Years with full driving licence”, “How many miles you travel on a typical day ?”, “Year of manufacture of your car”, “How do you rate your current driving skills compared to the best time of life ?”, "Muscular-skeletal complaints", "cardiovascular diseases", "Mental, nervous and sensory disorders", "digestive disorders", "genitourinary disorders", "skin complaints", "Tumours", "endocrine and metabolic disorders", "number of illnesses." Other variables were considered ordinal variables such as “how often do you have a drink containing alcohol”, “How many units of alcohol do you drink on a typical day when you

are drinking?", "Approximately how many miles do you drive in a typical year?", "What portion of your annual mileage is urban driving", "What portion of your annual mileage is interurban driving", "How often do you drive ?", "How often do you travel with other people?", "What is the engine size of your everyday vehicle?", "How do you rate your current driving ability in relation to your physical conditions", "How do you rate your current driving ability in relation to your mental capability?", "Do your current health conditions make it difficult to drive?", "Do you believe, given your current health conditions, that you will be able to continue driving over the next two years?; and the questions about driving at night: "Do you worry about merging into traffic?", "Do you feel stressed or get nervous?", "Do you feel that the roads are not sufficiently lit?", "Do you have difficulty seeing or understanding road markings?", "Do you have to slow down to read the road signs or street names?".

Other variables were coded as dummies, "gender", "Occupation", "smoking", "Do you have any driving qualifications other than the standard DSA driving test?", "Have you been involved in any road traffic accidents / collisions in the past 5 years? "," Have you ever stopped driving for longer than 3 months since you got your full driving licence?", "Have you had to stop driving due to health problems during the past 12 months?", "Have you ever fallen asleep behind the wheel?", "Do you see often the road signs at the last minute?", "Have you given up driving at night ?".

The answers to the question "have you ever driven the following vehicles?" were coded as five dummies.

So the variables included in the analysis were 50 and 31 drivers were tested, for this reason the survey has produced an indeterminate matrix, so to solve the problem only some variables have been considered and a factor analysis was performed.

7.2. Factorial analysis

With the aim to identify the latent variables (factors), able to explain the links, the interrelationships and dependencies between the statistical variables observed, a factor analysis was performed by the method of principal components. In the analysis the variables considered in the calculation of the DAI and the variables age, occupation and number of musculoskeletal diseases.

The variables included were the following: age, self-assessment of driving abilities compared to the best time of life (item 1), the self-assessment of driving abilities in relation to the physical and mental skills, the total number of diseases, the number of musculoskeletal diseases, the evaluation of the reduction of their driving skills because of diseases, abstaining from driving because of the diseases, prediction of their driving abilities in the following two years, the frequency of driving, the elapsed time from the last offense, involvement in accidents, the occurrence of falling asleep, identification of signals at the last minute, abstaining from driving at night, nervousness during night driving, road perception poorly lit, difficulties in the perception of the delimitations of the road in night driving, need to slow down to read the signs during night driving, occupation.

7.2.1. Preliminary tests for Factorial analysis

Because one of objectives of the analysis is to obtain factors that explain the correlations between the variables, these should be interconnected.

The presence of correlation can be tested by the Bartlett test of sphericity and with the Kaiser-Meyer-Olkin test (KMO).

The Bartlett sphericity test is applied to the correlation matrix, and the null hypothesis is that the matrix is equal to an identity matrix $\mathbf{H_0 : R = I}$.

$$\chi^2 = -\left[n - 1 - \frac{1}{6}(2p + 5)\right] ln \mid \mathbf{R} \mid$$

p = number of variables;

n = number of individuals;

|R| = determinant of the correlation matrix;

The test result is 453,852 and it as a Chi- squared distribution, with 210 degrees of freedom ($\frac{p^2-p}{2}$); so the p – value is 0,000, it is possible to reject the null hypothesis, that the correlation matrix is an identity matrix.

Table 17 Bartlett's Test

Bartlett's Test of Sphericity	Approx. Chi-Square	453,852
	degrees of freedom	210
	Significance	0,000

The Kaiser-Meyer-Olkin test (KMO) allows comparing the greatness of the observed correlations than the partial correlations.

$$KMO = \frac{\sum_i \sum_j r_{ij}^2}{\sum_i \sum_j r_{ij}^2 + \sum_i \sum_j p_{ij}^2}$$

r_{ij} = correlations;

p_{ij} = partial correlations.

Table 18 KMO Test

Test	Result
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0,526

The result can ranges from 0 to 1 and Kaiser in 1974 suggested that the results of the KMO test lower than 0.5 are not acceptable.

The test results suggest performing a factorial analysis.

7.2.2. Communalities

The communalities are the sum of the squares of the correlation coefficients between a variable and the extracted components.

Table 19 Communalities

Communalities		
	Initial	Extraction
How do you rate your current driving skills?	1,000	0,774
How do you rate your current driving ability in relation to your physical conditions?	1,000	0,847
How do you rate your current driving ability in relation to your mental capability?	1,000	0,909
Musculoskeletal complains	1,000	0,728
Total number of Diseases	1,000	0,760
Do your current health conditions make it difficult to drive?	1,000	0,824
Have you had to stop driving due to health problems during the past 12 months?	1,000	0,855
Do you believe, given your current health conditions, that you will be able to continue driving over the next two years?	1,000	0,933

How often do you drive?	1,000	0,792
Have you ever been caught committing a driving offence?	1,000	0,716
Have you been involved in any road traffic accidents/collisions in the past 5 years?	1,000	0,650
Have you ever fallen asleep behind the wheel?	1,000	0,442
Do you often see road signs at the last minute?	1,000	0,838
Have you given up driving at night?	1,000	0,843
When driving at night do you worry about merging into traffic?	1,000	0,595
When driving at night do you feel stressed or nervous?	1,000	0,912
When driving at night do you feel that the road is not sufficiently lit	1,000	0,728
When driving at night do you have difficulty seeing or understanding road markings?	1,000	0,806
Do you have to slow down to read the road signs or street names?	1,000	0,716
Occupation	1,000	0,501
Age	1,000	0,729

In the following table is shown the component matrix obtained without the rotation of the factorial axes, the variables have been coloured on basis of the factor in which they have the highest weight.

Table 20 Matrix of components without rotation

	Component					
	1	2	3	4	5	6
Age	-0,514	-0,437	-0,341	0,249	-0,306	-0,03
How do you rate your current driving skills?	0,54	0,482	-0,024	0,351	-0,238	0,264
How do you rate your current driving ability in relation to your physical conditions?	0,59	0,559	-0,305	0,302	-0,042	-0,029
How do you rate your current driving ability in relation to your mental capability?	0,61	0,514	-0,106	0,503	-0,062	-0,072
musculoskeletal complains	-0,068	-0,653	0,276	0,451	0,114	0,071
Total number of Diseases	-0,095	-0,603	0,263	0,542	0,023	0,153
Do your current health conditions make it difficult to drive?	0,837	0,203	0,007	0,13	-0,034	0,253
Have you had to stop driving due to health problems during the past 12 months?	0,85	-0,249	-0,112	-0,169	-0,071	-0,158
Do you believe, given your current health conditions, that you will be able to continue driving over the next two years?	0,726	0,165	0,549	0,074	-0,258	0,074

How often do you drive?	-0,062	0,207	0,064	0,467	0,305	-0,656
Have you ever been caught committing a driving offence?	-0,347	-0,249	-0,667	0,164	-0,092	-0,232
Have you been involved in any road traffic accidents/collisions in the past 5 years?	0,244	0,089	0,087	-0,129	0,732	-0,152
Have you ever fallen asleep behind the wheel?	0,01	0,546	-0,125	-0,139	0,322	-0,074
Do you often see road signs at the last minute?	0,331	-0,15	-0,468	0,005	0,411	0,564
Have you given up driving at night?	0,668	-0,204	0,438	-0,297	-0,16	-0,221
When driving at night do you worry about merging into traffic?	-0,712	0,21	0,128	-0,125	0,046	0,097
When driving at night do you feel stressed or nervous?	-0,812	0,366	0,237	0,222	-0,11	-0,036
When driving at night do you feel that the road is not sufficiently lit	-0,701	0,353	0,203	-0,023	0,056	0,258
When driving at night do you have difficulty seeing or understanding road markings?	-0,845	0,222	0,112	0,145	0,031	0,096
Do you have to slow down to read the road signs or street names?	-0,704	0,447	0,113	0,001	-0,059	0,067
Occupation	0,12	-0,208	0,257	0,264	0,536	0,145

7.2.3. Rotation of the factorial axes

By rotation the weights of some factors that were already low in the previous steps are reduced and the weights that were high in the first stage increase.

Factors rotated were extracted with techniques Varimax, Oblimin, Promax and Quadrimax.

Below the matrices of the components obtained with the different rotation methods are shown and the variables have been coloured on basis of the factor in which they have the highest weight.

Varimax rotation is an orthogonal rotation of the factor axes, that allows maximising the variance of the squared loadings of a factor on all the variables in a factor matrix, which has the effect of differentiating the original variables by extracted factor.

The matrix of components is shown below.

Table 21 Matrix of components - Rotation Varimax

	Component					
	1	2	3	4	5	6
Age	0,158	-0,227	-0,604	0,337	-0,416	0,012
How do you rate your current driving skills?	-0,095	0,82	0,243	-0,074	-0,113	-0,119
How do you rate your current driving ability in relation to your physical conditions?	-0,241	0,827	-0,018	-0,307	0,089	0,05
How do you rate your current driving ability in relation to your mental capability?	-0,21	0,897	0,091	-0,091	0,086	0,194
Muscular skeletal complains	-0,077	-0,16	-0,04	0,83	0,065	0,049
Total number of Diseases	-0,002	-0,059	-0,052	0,868	-0,023	0,012
Do your current health conditions make it difficult to drive?	-0,485	0,63	0,354	-0,037	0,09	-0,239
Have you had to stop driving due to health problems during the past 12 months?	-0,893	0,147	0,173	-0,07	0,007	-0,043
Do you believe, given your current health conditions, that you will be able to continue driving over the next two years?	-0,362	0,42	0,773	0,095	-0,119	0,072
How often do you drive?	0,08	0,209	-0,189	0,069	0,358	0,757
Have you ever been caught committing a driving offence?	-0,022	-0,106	-0,817	0,006	-0,177	0,08
Have you been involved in any road traffic accidents/collisions in the past 5 years?	-0,164	-0,057	0,118	-0,129	0,765	0,071
Have you ever fallen asleep behind the wheel?	0,184	0,188	0,004	-0,487	0,365	0,047
Do you often see road signs at the last minute?	-0,265	0,209	-0,255	0,057	0,389	-0,711
Have you given up driving at night?	-0,649	-0,092	0,62	-0,002	-0,076	0,155
When driving at night do you worry about merging into traffic?	0,699	-0,301	-0,051	-0,112	-0,026	0,003
When driving at night do you feel stressed or nervous?	0,892	-0,067	-0,061	0,021	-0,153	0,29
When driving at night do you feel that the road is not sufficiently lit	0,834	-0,137	0,046	-0,078	0,002	-0,076
When driving at night do you have difficulty seeing or understanding road markings?	0,853	-0,181	-0,178	0,057	-0,046	0,091
Do you have to slow down to read the road signs or street names?	0,806	-0,076	-0,041	-0,198	-0,099	0,099
Occupation	-0,022	0,018	0,125	0,437	0,539	-0,059

Oblimin rotation is a non-orthogonal (oblique) solution, in which the factors are allowed to be correlated. This usually results in higher eigenvalues but diminished interpretability of the factors.

Table 22 Matrix of components Rotation Oblimin

	Component					
	1	2	3	4	5	6
Age	-0,241	-0,358	-0,651	-0,354	-0,461	-0,032
How do you rate your current driving skills?	0,212	0,143	0,304	0,836	-0,051	0,122
How do you rate your current driving ability in relation to your physical conditions?	0,319	0,357	0,072	0,879	0,162	-0,025
How do you rate your current driving ability in relation to your mental capability?	0,311	0,154	0,173	0,931	0,156	-0,17
Muscular skeletal complains	0,087	-0,844	-0,062	-0,22	0,019	-0,033
Total number of Diseases	0,024	-0,869	-0,079	-0,142	-0,067	-0,006
Do your current health conditions make it difficult to drive?	0,597	0,069	0,451	0,73	0,15	0,287
Have you had to stop driving due to health problems during the past 12 months?	0,914	0,037	0,286	0,304	0,047	0,132
Do you believe, given your current health conditions, that you will be able to continue driving over the next two years?	0,483	-0,055	0,828	0,513	-0,07	-0,043
How often do you drive?	-0,089	-0,053	-0,182	0,192	0,368	-0,75
Have you ever been caught committing a driving offence?	-0,082	-0,038	-0,818	-0,179	-0,198	-0,076
Have you been involved in any road traffic accidents/collisions in the past 5 years?	0,179	0,109	0,155	0,042	0,772	-0,036
Have you ever fallen asleep behind the wheel?	-0,172	0,506	0,017	0,224	0,393	-0,06
Do you often see road signs at the last minute?	0,296	-0,071	-0,195	0,246	0,395	0,746
Have you given up driving at night?	0,686	-0,021	0,679	0,056	-0,05	-0,095
When driving at night do you worry about merging into traffic?	-0,735	0,125	-0,148	-0,399	-0,061	-0,075
When driving at night do you feel stressed or nervous?	-0,907	0,025	-0,174	-0,222	-0,181	-0,382
When driving at night do you feel that the road is not sufficiently lit	-0,834	0,114	-0,056	-0,253	-0,027	-0,01

When driving at night do you have difficulty seeing or understanding road markings?	-0,883	-0,028	-0,289	-0,333	-0,087	-0,176
Do you have to slow down to read the road signs or street names?	-0,822	0,236	-0,135	-0,192	-0,117	-0,184
Occupation	0,07	-0,437	0,129	0,027	0,521	0,076

Promax rotation is an alternative non-orthogonal rotation method (oblique), which is sometimes used for very large datasets.

Table 23 Matrix of components Rotation Promax

	Component					
	1	2	3	4	5	6
Age	0,277	-0,395	-0,644	0,396	-0,434	0,057
How do you rate your current driving skills?	-0,251	0,823	0,368	-0,154	0,009	-0,153
How do you rate your current driving ability in relation to your physical conditions?	-0,342	0,886	0,157	-0,365	0,236	-0,037
How do you rate your current driving ability in relation to your mental capability?	-0,339	0,926	0,258	-0,169	0,208	0,107
Muscularskeletal complains	-0,073	-0,228	-0,076	0,842	-0,01	0,029
Total number of Diseases	-0,015	-0,162	-0,091	0,87	-0,085	0,006
Do your current health conditions make it difficult to drive?	-0,632	0,759	0,528	-0,089	0,206	-0,339
Have you had to stop driving due to health problems during the past 12 months?	-0,918	0,353	0,395	-0,047	0,081	-0,188
Do you believe, given your current health conditions, that you will be able to continue driving over the next two years?	-0,528	0,514	0,886	0,021	-0,097	0,031
How often do you drive?	0,104	0,182	-0,171	0,041	0,323	0,706
Have you ever been caught committing a driving offence?	0,125	-0,192	-0,785	0,077	-0,14	0,062
Have you been involved in any road traffic accidents/collisions in the past 5 years?	-0,178	0,103	0,121	-0,137	0,747	-0,013
Have you ever fallen asleep behind the wheel?	0,162	0,244	-0,008	-0,516	0,401	0,041
Do you often see road signs at the last minute?	-0,297	0,303	-0,192	0,076	0,497	-0,795
Have you given up driving at night?	-0,703	0,085	0,742	-0,006	-0,099	0,083
When driving at night do you worry about merging into traffic?	0,738	-0,431	-0,246	-0,117	-0,102	0,134
When driving at night do you feel stressed or nervous?	0,907	-0,289	-0,263	-0,018	-0,237	0,444
When driving at night do you feel that the road is not sufficiently lit	0,825	-0,291	-0,167	-0,111	-0,063	0,071
When driving at night do you have difficulty seeing or understanding road markings?	0,889	-0,383	-0,392	0,04	-0,124	0,233

Do you have to slow down to read the road signs or street names?	0,818	-0,239	-0,222	-0,229	-0,151	0,241
Occupation	-0,073	0,056	0,087	0,416	0,5	-0,107

Quartimax rotation is an orthogonal rotation of the factor axes that minimizes the number of factors needed to explain each variable.

The matrix of components is shown below.

Table 24 Matrix of components Rotation Quadrimax

	Component					
	1	2	3	4	5	6
Age	0,212	-0,223	-0,594	0,341	-0,406	0,004
How do you rate your current driving skills?	-0,161	0,813	0,231	-0,074	-0,124	-0,115
How do you rate your current driving ability in relation to your physical conditions?	-0,284	0,813	-0,04	-0,308	0,079	0,055
How do you rate your current driving ability in relation to your mental capability?	-0,262	0,885	0,07	-0,092	0,076	0,197
Muscular skeletal complains	-0,074	-0,167	-0,041	0,828	0,067	0,05
Total number of Diseases	-0,006	-0,062	-0,049	0,868	-0,021	0,01
Do your current health conditions make it difficult to drive?	-0,553	0,599	0,321	-0,044	0,072	-0,221
Have you had to stop driving due to health problems during the past 12 months?	-0,909	0,093	0,116	-0,082	-0,011	-0,01
Do you believe, given your current health conditions, that you will be able to continue driving over the next two years?	-0,43	0,399	0,745	0,089	-0,135	0,092
How often do you drive?	0,099	0,22	-0,188	0,072	0,366	0,748
Have you ever been caught committing a driving offence?	0,042	-0,11	-0,818	0,009	-0,168	0,074
Have you been involved in any road traffic accidents/collisions in the past 5 years?	-0,176	-0,06	0,114	-0,133	0,762	0,073
Have you ever fallen asleep behind the wheel?	0,173	0,203	0,016	-0,485	0,366	0,038
Do you often see road signs at the last minute?	-0,294	0,189	-0,263	0,053	0,38	-0,707
Have you given up driving at night?	-0,672	-0,129	0,576	-0,012	-0,091	0,186
When driving at night do you worry about merging into traffic?	0,719	-0,258	-0,006	-0,104	-0,012	-0,021
When driving at night do you feel stressed or nervous?	0,909	-0,012	-0,008	0,034	-0,135	0,259
When driving at night do you feel that the road is not sufficiently lit	0,833	-0,086	0,1	-0,068	0,015	-0,105
When driving at night do you have difficulty seeing or understanding road markings?	0,875	-0,129	-0,124	0,068	-0,028	0,059
Do you have to slow down to read the road signs or street names?	0,817	-0,026	0,009	-0,188	-0,084	0,071
Occupation	-0,048	0,019	0,13	0,435	0,537	-0,061

Varimax rotation was the technique that produced the best results. The only factors with eigenvalues greater than one were chosen, and a structure with six factors was obtained, by which 75.72% of the variance is explained.

Table 25 Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	% of Variance
1	6,861	32,674	32,674	6,861	32,674
2	2,990	14,240	46,913	2,990	14,240
3	1,769	8,423	55,337	1,769	8,423
4	1,602	7,627	62,964	1,602	7,627
5	1,487	7,081	70,045	1,487	7,081
6	1,192	5,677	75,722	1,192	5,677
7	,985	4,692	80,414		
8	,935	4,451	84,866		
9	,769	3,662	88,528		
10	,563	2,680	91,208		
11	,474	2,258	93,466		
12	,335	1,597	95,062		
13	,259	1,235	96,297		
14	,186	,884	97,182		
15	,174	,829	98,011		
16	,134	,638	98,649		
17	,095	,451	99,100		
18	,073	,349	99,450		
19	,064	,303	99,753		
20	,043	,203	99,956		
21	,009	,044	100,000		

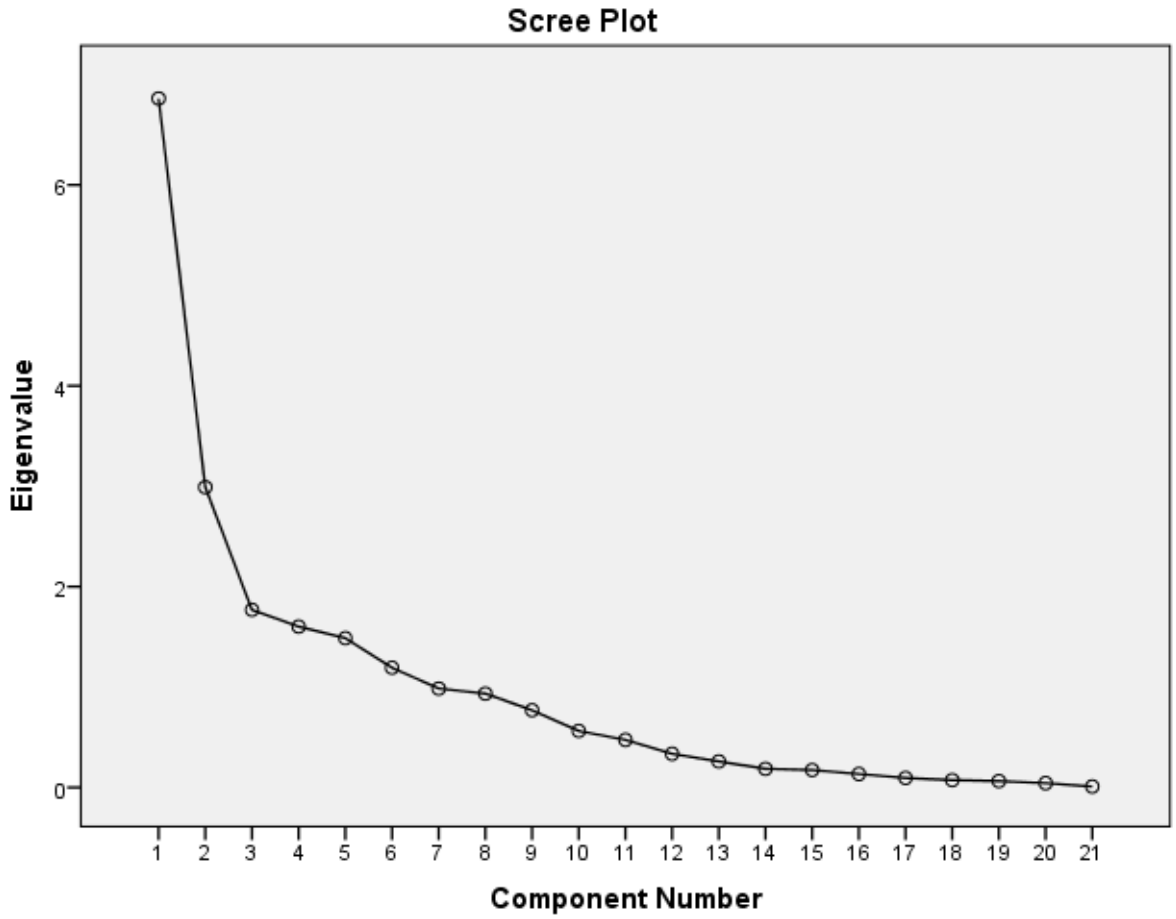

Figure 75 Scree plot

The following table shows the matrix of components.

Table 26 Matrix of components

	Component					
	1	2	3	4	5	6
Have you had to stop driving due to health problems during the past 12 months?	-0,893					
Have you given up driving at night?	-0,649					
When driving at night do you worry about merging into traffic?	0,699					
When driving at night do you feel stressed or nervous?	0,892					
When driving at night do you feel that the road is not sufficiently lit	0,834					
When driving at night do you have difficulty seeing or understanding road markings?	0,853					
Do you have to slow down to read the road signs or street names?	0,806					
Do your current health conditions make it difficult to drive?		0,63				
How do you rate your current driving skills?		0,82				
How do you rate your current driving ability in relation to your physical conditions?		0,827				
How do you rate your current driving ability in relation to your mental capability?		0,897				
Age			-0,604			
Do you believe, given your current health conditions, that you will be able to continue driving over the next two years?			0,773			
Have you ever been caught committing a driving offence?			-0,817			
Musculoskeletal complains				0,83		
Total number of Diseases				0,868		
Have you ever fallen asleep behind the wheel?				-0,487		
Have you been involved in any road traffic accidents/collisions in the past 5 years?					0,765	
Occupation					0,539	
How often do you drive?						0,757
Do you often see road signs at the last minute?						-0,711

7.2.4. Interpretation of the factors

The **first factor** is about the difficulties driving, it explains the 32,67% of the variance and it includes the variables:

Have you had to stop driving due to health problems during the past 12 months?

Have you given up driving at night?

When driving at night do you worry about merging into traffic?

When driving at night do you feel stressed or nervous?

When driving at night do you feel that the road is not sufficiently lit

When driving at night do you have difficulty seeing or understanding road markings?

Do you have to slow down to read the road signs or street names?

The **second factor** explains the 14,24 % of the variance, it refers to the self-assessment of driving abilities and it includes the variables:

Do your current health conditions make it difficult to drive?

How do you rate your current driving skills?

How do you rate your current driving ability in relation to your physical conditions?

How do you rate your current driving ability in relation to your mental capability?

The **third factor** refers to the driving conditions current and future, it explains the 8,42% of the variance and it includes the variables:

Age

Do you believe, given your current health conditions, that you will be able to continue driving over the next two years?

Have you ever been caught committing a driving offence?

The **fourth factor** explains the 7,63% of the variance and it is relative to the health and physical well-being and includes the variables:

Musculoskeletal complains

Total number of Diseases

Have you ever fallen asleep behind the wheel?

The **fifth factor** refers to the level of activity, it explains the 7,08% of the variance and involvement in accidents and includes the variables:

Have you been involved in any road traffic accidents/collisions in the past 5 years?

Occupation

The **sixth factor** refers to driving behaviour, it explains the 5,68% of the variance and it includes the variables:

How often do you drive?

Do you often see road signs at the last minute?

The matrix component allows to write the relationships between variables and factors found:

Age = 0,158 * F1 -0,227 * F2 -0,604 * F3 + 0,337 * F4 -0,416 * F5 + 0,012 * F6

How do you rate your current driving skills? = -0,095 * F1 + 0,82 * F2 + 0,243 * F3 -0,074 * F4 -0,113 * F5 -0,119 * F6

How do you rate your current driving ability in relation to your physical conditions? = -0,241 * F1 0,827 * F2 -0,018 * F3 -0,307 * F4 + 0,089 * F5 + 0,05 * F6

How do you rate your current driving ability in relation to your mental capability? = -0,21 * F1 0,897 * F2 + 0,091 * F3 + -0,091 * F4 + 0,086 * F5 + 0,194 * F6

Muscular skeletal complains = -0,077 * F1 -0,16 * F2 -0,04 * F3 + 0,83 * F4 + 0,065 * F5 + 0,049 * F6

Total number of Diseases = -0,002 * F1 -0,059 * F2 -0,052 * F3 + 0,868 * F4 + -0,023 * F5 + 0,012 * F6

Do your current health conditions make it difficult to drive? =-0,485 * F1 +0,63 * F2 + 0,354 * F3 -0,037 * F4 + 0,09 * F5 -0,239 * F6

Have you had to stop driving due to health problems during the past 12 months? = -0,893 * F1 + 0,147 * F2 + 0,173 * F3 + -0,07 * F4 + 0,007 * F5 + -0,043 * F6

Do you believe, given your current health conditions, that you will be able to continue driving over the next two years? = -0,362 * F1 + 0,42 * F2 + 0,773 * F3 + 0,095 * F4 -0,119 * F5 + 0,072 * F6

How often do you drive? = 0,08 * F1 + 0,209 * F2 + -0,189 * F3 + 0,069 * F4 + 0,358 * F5 + 0,757 * F6

Have you ever been caught committing a driving offence? = -0,022 * F1 -0,106 * F2 + -0,817 * F3 + 0,006 * F4 + -0,177 * F5 + 0,08 * F6

Have you been involved in any road traffic accidents/collisions in the past 5 years? = -0,164 * F1 -0,057 * F2 + 0,118 * F3 + -0,129 * F4 + 0,765 * F5 + 0,071 * F18

Have you ever fallen asleep behind the wheel? = 0,184 * F1 0,188 * F2 + 0,004 * F3 + -0,487 * F4 + 0,365 * F5 + 0,047 * F6

Do you often see road signs at the last minute? = -0,265 * F1 0,209 * F2 + -0,255 * F3 + 0,057 * F4 + 0,389 * F5 + -0,711 * F6

Have you given up driving at night? =0,649 * F1 -0,092 * F2 + 0,62 * F3 + -0,002 * F4 + -0,076 * F5 + 0,155 * F6

When driving at night do you worry about merging into traffic? = 0,699 * F1 -0,301 * F2 -0,051 * F3 -0,112 * F4 -0,026 * F5 + 0,003 * F6

When driving at night do you feel stressed or nervous? = 0,892 * F1 -0,067 * F2 -0,061 * F3 + 0,021 * F4 -0,153 * F5 + 0,29 * F6

When driving at night do you feel that the road is not sufficiently lit? = 0,834 * F1 -0,137 * F2 + 0,046 * F3 -0,078 * F4 + 0,002 * F5 -0,076 * F6

When driving at night do you have difficulty seeing or understanding road markings? = 0,853 * F1 -0,181 * F2 -0,178 * F3 + 0,057 * F4 + -0,046 * F5 + 0,091 * F6

Do you have to slow down to read the road signs or street names? = 0,806 * F1 -0,076 * F2 + -0,041 * F3 + -0,198 * F4 + -0,099 * F5 + 0,099 * F6

Occupation = -0,022 * F1 0,018 * F2 + 0,125 * F3 + 0,437 * F4 + 0,539 * F5 -0,059 * F6

The relationships between factors and variables are:

Factor 1 = 0,158 * Age + -0,095 * How do you rate your current driving skills? -0,241 * How do you rate your current driving ability in relation to your physical conditions? + -0,21 * How do you rate your current driving ability in relation to your mental capability? -0,077 * Muscular skeletal complains + -0,002 * Total number of Diseases -0,485 * Do your current health conditions make it difficult to drive? -0,893 * Have you had to stop driving due to health problems during the past 12 months? -0,362 * Do you believe, given your current health conditions, that you will be able to continue driving over the next two years? + 0,08 * How often do you drive? -0,022 * Have you ever been caught committing a driving offence? -0,164 * Have you been involved in any road traffic accidents/collisions in the past 5 years? = + 0,184 * Have you ever fallen asleep behind the wheel? -0,265 * Do you often see road signs at the last minute? -0,649 * Have you given up driving at night? + 0,699 * When driving at night do you worry about merging into traffic? + 0,892 * When driving at night do you feel stressed or nervous? + 0,834 * When driving at night do you feel that the road is not sufficiently lit? + 0,853 *When driving at night do you have difficulty seeing or understanding road markings?+ 0,806 *Do you have to slow down to read the road signs or street names? -0,022 * Occupation

Factor 2 = -0,227 * Age + 0,82 * How do you rate your current driving skills? + 0,827 * How do you rate your current driving ability in relation to your physical conditions? + 0,897 * How do you rate your current driving ability in relation to your mental capability? -0,16 * Muscular skeletal complains -0,059 * Total number of Diseases + 0,63 * Do your current health conditions make it difficult to drive? + 0,147 * Have you had to stop driving due to health problems during the past 12 months? + 0,42 * Do you believe, given your current health conditions, that you will be able to continue driving over the next two years? + 0,209 * How often do you drive? -0,106 * Have you ever been caught committing a driving offence? -0,057 * Have you been involved in any road traffic accidents/collisions in the past 5 years? + 0,188 * Have you ever fallen asleep behind the wheel? + 0,209 * Do you often see road signs at the last minute? -0,092 * Have you given up driving at night? -0,301 * When driving at night do you worry about merging into traffic? -0,067 * When driving at night do you feel stressed or nervous? -0,137 * When driving at night do you feel that the road is not sufficiently lit? -0,181 *When driving at night do you have difficulty seeing or understanding road markings? -0,076 *Do you have to slow down to read the road signs or street names? + 0,018 * Occupation

Factor 3 = -0,604 * Age + 0,243 * How do you rate your current driving skills? -0,018 * How do you rate your current driving ability in relation to your physical conditions? + 0,091 * How do you rate your current driving ability in

relation to your mental capability? -0,04 * Muscular skeletal complains - 0,052 * Total number of Diseases + 0,354 * Do your current health conditions make it difficult to drive? + 0,173 * Have you had to stop driving due to health problems during the past 12 months? + 0,773 * Do you believe, given your current health conditions, that you will be able to continue driving over the next two years? -0,189 * How often do you drive? -0,817 * Have you ever been caught committing a driving offence? + 0,118 * Have you been involved in any road traffic accidents/collisions in the past 5 years? + 0,004 * Have you ever fallen asleep behind the wheel? + -0,255 * Do you often see road signs at the last minute? + 0,62 * Have you given up driving at night? -0,051 * When driving at night do you worry about merging into traffic? -0,061 * When driving at night do you feel stressed or nervous? + 0,046 * When driving at night do you feel that the road is not sufficiently lit? - 0,178 * When driving at night do you have difficulty seeing or understanding road markings? - 0,041 * Do you have to slow down to read the road signs or street names? + 0,125 * Occupation

Factor 4 = 0,337 * Age - 0,074 * How do you rate your current driving skills? -0,307 * How do you rate your current driving ability in relation to your physical conditions? - 0,091 * How do you rate your current driving ability in relation to your mental capability? + 0,83 * Muscular skeletal complains + 0,868 * Total number of Diseases - 0,037* Do your current health conditions make it difficult to drive? - 0,07 * Have you had to stop driving due to health problems during the past 12 months? + 0,095 * Do you believe, given your current health conditions, that you will be able to continue driving over the next two years? + 0,069 * How often do you drive? + 0,006 * Have you ever been caught committing a driving offence? - 0,129 * Have you been involved in any road traffic accidents/collisions in the past 5 years? - 0,487 * Have you ever fallen asleep behind the wheel? + 0,057 * Do you often see road signs at the last minute? - 0,002* Have you given up driving at night? -0,112 * When driving at night do you worry about merging into traffic? + 0,021 * When driving at night do you feel stressed or nervous? - 0,078* When driving at night do you feel that the road is not sufficiently lit? + 0,057 *When driving at night do you have difficulty seeing or understanding road markings? - 0,198 *Do you have to slow down to read the road signs or street names? 0,437 * Occupation

Factor 5 = -0,416 * Age - 0,113* How do you rate your current driving skills? + 0,089 * How do you rate your current driving ability in relation to your physical conditions? + 0,086 * How do you rate your current driving ability in relation to your mental capability? + 0,065 * Muscular skeletal complains - 0,023 * Total number of Diseases + 0,09 * Do your current health conditions make it difficult to drive? + 0,007 * Have you had to stop driving due to health problems during the past 12 months? - 0,119* Do you believe, given your current health conditions, that you will be able to

continue driving over the next two years? + 0,358 * How often do you drive? - 0,177 * Have you ever been caught committing a driving offence? + 0,765 * Have you been involved in any road traffic accidents/collisions in the past 5 years? + 0,365 * Have you ever fallen asleep behind the wheel? + 0,389 * Do you often see road signs at the last minute? - 0,076 * Have you given up driving at night? - 0,026 * When driving at night do you worry about merging into traffic? - 0,153 * When driving at night do you feel stressed or nervous? + 0,002 * When driving at night do you feel that the road is not sufficiently lit? - 0,046 *When driving at night do you have difficulty seeing or understanding road markings? - 0,099 *Do you have to slow down to read the road signs or street names? + 0,539 * Occupation

Factor 6 = 0,012 * Age - 0,119 * How do you rate your current driving skills? + 0,05 * How do you rate your current driving ability in relation to your physical conditions? + 0,194 * How do you rate your current driving ability in relation to your mental capability? + 0,049 * Muscular skeletal complains + 0,012 * Total number of Diseases - 0,239 * Do your current health conditions make it difficult to drive? - 0,043 * Have you had to stop driving due to health problems during the past 12 months? + 0,072 * Do you believe, given your current health conditions, that you will be able to continue driving over the next two years? + 0,757 * How often do you drive? + 0,08 * Have you ever been caught committing a driving offence? + 0,071 * Have you been involved in any road traffic accidents/collisions in the past 5 years? + 0,047 * Have you ever fallen asleep behind the wheel? - 0,711 * Do you often see road signs at the last minute? + 0,155 * Have you given up driving at night? + 0,003 * When driving at night do you worry about merging into traffic? + 0,29 * When driving at night do you feel stressed or nervous? - 0,076 * When driving at night do you feel that the road is not sufficiently lit? + 0,091 *When driving at night do you have difficulty seeing or understanding road markings? + 0,099 * Do you have to slow down to read the road signs or street names? - 0,059 * Occupation

7.2.5. Linear regression

The factors so obtained have been used for the construction of a linear regression relation in order to predict the ability to drive on the road.

The estimated relation does not have a good level of general adaptation as shown by the R^2=0, 571, so about 57% of the variability observed in the ability to drive is explained through the six factors included in the model.

R is 0.756 and it represents the correlation coefficient between the observed value of the dependent variable and the predicted value based on the regression model.

The analysis of variance is used to test the null hypothesis that there is no linear relationship in the population between the dependent variable and the independent variables, that all the partial regression coefficient are 0, and that the population value for multiple R^2 is 0.

The ratio of the mean squares is 5.331, the observed significance level is less than 0,001, so the null hypothesis can be rejected.

Among the variables included in the regression only the factors 2 and 3, which are related to self-assessment of driving abilities and current and future driving conditions, are very significant (t-test> 1.96), while the other factors included have a significance level lower than the 54.7%, and the constant is very significant (t-test = 17.908).

The coefficients related to each factor are shown in the following table.

Table 27 Parameter estimated in the linear regression

	Coefficient unstandardized	Standardized Coefficients	t-test
	T	Beta	
(Constant)	2,290		17,908
Factor 1	- 0,010	-0,011	-0,079
Factor 2	0,275	0,283	2,116
Factor 3	0,668	0,687	5,137
Factor 4	-0,099	-0,102	-0,762
Factor 5	-0,009	-0,009	-0,066
Factor 6	0,095	0,097	0,728

Given the low level of general adaptation of the model and the reduced level of significance of the variables, the model estimated by the factors is not is not sufficient to predict the ability to drive, for this reason another model was estimated by linear regression techniques.

7.3. Estimation of the relation with a linear regression

To estimate the relation, all the variables listed in the previous paragraph have been considered, and to avoid the problem of the indeterminate matrix, the estimation was done with SPSS software through the stepwise technique (criterion for entry or removal of variables are the probabilities of F, respectively, 0.05 and 0.10) after some iterations the less significant variables and the variable with a coefficient with incorrect sign were excluded.

The best relation includes five variables which are:

- Age (continuous variable);
- Occupation (Dummy variable coded as 0 = retired, 1 = he/she is still working);
- Do you believe, given your current health conditions, that you will be able to continue driving over the next two years? (Ordinal variable whose responses were coded as such: 1 = Highly unlikely, 2 = Not sure, 3 = Maybe, 4 = Definitely);
- Have you been Involved in any road traffic accidents / collisions in the past 5 years? (Dummy variable coded as 0 = no, 1 = yes);
- Number of muscular skeletal complaints (continuous variable).

Driving Ability= -0,049 * **Age** + 1,737***Driving in the next two years** -1,013 ***Accident** + 0,919* **Occupation** - 0,270***Number of musculoskeletal complains** -0,830

Table 28 Parameter estimated in the linear regression

	Unstandardized Coefficients	Standardized Coefficients	t-test
	T	Beta	
(Constant)	-0,830		-0,286
Age	-0,049	-0,381	-2,636
Do you believe, given your current health conditions, that you will be able to continue driving over the next two years?	1,737	0,446	3,389
Have you been involved in any road traffic accidents/collisions in the past 5 years? Have you been involved in any road traffic accidents/collisions in the past 5 years?	-1,013	-0,355	-2,941
Occupation	0,919	0,284	2,427
Number of Muscular skeletal complains	-0,270	-0,273	-2,290

The model has a good level of general adaptation as R^2 = 0, 693 shows, then about 70% of the variability observed in the ability to drive is explained through the five variables included in the model.

R is 0.832 and it represents the correlation coefficient between the observed value of the dependent variable and the predicted value based on the regression model.

The analysis of variance is used to test the null hypothesis that there is no linear relationship in the population between the dependent variable and the independent variables, that all of the partial regression coefficient are 0, and that the population value for multiple R^2 is 0. The ratio of the mean squares is 11,276, the observed significance level is less than 0,0005, so the null hypothesis can be rejected.

All variables included in the model are highly significant (t-test> 1.96), the constant is not significant (t-test = 0.286).

The variable Age has a negative coefficient that amounts to -0,049, so age negatively affects driving performance, and it is very significant because the t-test is -2.636.

The coefficient associated with the variable "Driving in the next two years" is 1,737, then the prediction of driving skills in the next two years reflects the current driving capability. This coefficient is significantly different from zero (the t-test is 3.389).

The accident involvement is very significant, because the t-test amounts to -2.941, and the regression coefficient is negative and is -1.013, in fact, this dummy variable is included in the model only in the event of accident involvement and has a negative influence on the ability to drive.

Even the variable "Occupation" is a dummy variable, and it is considered in the model only if the driver is still working, the coefficient associated with this variable is 0.919 and has a high level the significance (t-test = 2.427).

The variable "Number of Muscular skeletal complains" has a negative coefficient equal to -0.270, in fact, if the number of musculoskeletal diseases grows as driving ability decreases; because for drivers that have musculoskeletal diseases is more difficult to use the vehicle controls, and also check the stimuli present in the environment is difficult because the rotations of the head required to control junctions and in reverse manoeuvres are difficult to perform. This variable is very significant as shown by the t-test that amounts to -2.290.

Table 29 Parameter estimated in the linear regression

		Driving Ability	Age	Number of Muscular skeletal complains	Driving ability in next two years	Accident	Occupation
Driving Ability	Pearson Correlation	1	-0,586	-0,289	0,629	-0,117	0,243
	Sign. (1-tailed)		0,000	0,057	0,000	0,266	0,094
Age	Pearson Correlation	-0,586	1	0,225	-0,515**	-0,349*	-0,131
	Sign. (1-tailed)	0,000		0,111	0,002	0,027	0,241
Number of Muscularskeletal complains	Pearson Correlation	-0,289	0,225	1	0,009	-0,013	0,215
	Sign. (1-tailed)	0,057	0,111		0,481	0,473	0,123
Driving ability in next	Pearson Correlation	0,629	-0,515	0,009	1	0,101	0,086
	Sign. (1-tailed)	0,000	0,002	0,481		0,294	0,323
Accident	Pearson Correlation	-0,117	-0,349	-0,013	0,101	1	0,199
	Sign. (1-tailed)	0,266	0,027	0,473	0,294		0,141
Occupation	Pearson Correlation	0,243	-0,131	0,215	0,086	0,199	1
	Sign. (1-tailed)	0,094	0,241	0,123	0,323	0,141	

The table above is the matrix of "Pearson correlation coefficients" for all variables included in the model, these suggest that the independent variables included in the model are not related to each other, the highest correlation coefficient between the variables present amounted to 0,515 between the variables "age" and "driving ability in next two years".

8. CONCLUSIONS

With the increase in life expectancy, the elderly have a more active role in society and tend to use the car for their journeys. Being able to drive ensures their independence and participation in social life, but with aging many of the physical abilities and cognitive skills required for driving deteriorate. For this reason in the present study an easy to manage tool, has been developed, which have been adapted from a context other than the field of driving, and it may be used to assess fitness to drive in elderly people and also to identify the main signs of decline in those skills needed to drive a car.

The proposed relation, estimated using multiple linear regression techniques, explains 70% of the variance in ability to drive. It is also simple to apply and requires a limited amount of input information, so it may be used when renewing driving licenses to identify elderly people with poor driving skills, who may put others and themselves at risk every time they get behind the wheel.

Batteries of tests rather than single tests are most commonly used in driver assessment so, the advantage of the test proposed in this thesis is that it is a single test with simple questions making it easy for the driver to answer and complete.

The Driving Ability Index questionnaire also identifies drivers with moderate driving ability and therefore still able to drive, though with some difficulty. These drivers could benefit from in-car assistance systems, which are suitable for the compensating for the deficits indicated in section 3 of the questionnaire.

For example, automatic transmission reduces the stress on the lower limbs and especially on the left leg, while in the case of cervical spine disorders or limited neck mobility the reversing camera can be useful as it allows drivers to perform the manoeuvers without rotating the head. Adaptive cruise control systems are radar sensors that detect the presence of obstacles around the vehicle allowing the driver to perceive what happens at 360° in real time. These devices also provide automatic braking or adjust speed automatically to match the traffic conditions. These instruments allow drivers to perceive stimuli present in the edges of the visual field and to reduce the mental workload, which can be helpful for elderly drivers who usually have a reduced field of vision and are slower to process information, especially if they have sensory impairments.

The last part of the questionnaire contains questions that investigate the difficulties experienced in night driving. It could be recommended that people who encounter major problems only drive during daylight, as happens in Australia.

For the elderly with moderate driving skills the hypothesis of restricting car use to within a certain distance from home could be considered, so as to prevent isolation and ensure participation in social life.

The results of the proposed linear regression and factorial analysis indicated that the ability to drive depends on age, physical abilities and cognitive skills, self-assessment of current and future driving ability and on driving behaviour and habits. Thus, for license renewal it is not sufficient to verify just one physical ability (usually eyesight) as often happens.

Using the estimated model we propose a useful and easy to manage tool, that can also be used for the renewal of driving licences, making it possible to identify elderly drivers who may be at risk or would benefit from in-car assistance systems.

In the self-assessment of driving skills marked differences were found in the two genders. Women tend to underestimate their own driving skills compared to their peers of the opposite gender. For this reason, future research could focus on extending the same experiment to include a greater number of women, in order to estimate separately the answers to the questionnaire for the two genders.

9. BIBLIOGRAPHY

Publications of the author

Pinna C., Analisi sperimentale della precezione visiva in età senile, Tesi di Laurea 2011.

Fancello G., Pinna C. and Fadda P. 2012."**The vision of roundabout by elderly drivers**" , in Neville A. Stanton (eds) "Advances in Human Aspects of Road and Rail Transportation" CRC Press Taylor & Francis Group ISBN 13: 978-0-9796435-5-2; ISBN 10: 0-9796435-5-4.

Fancello G., Pinna C. and Fadda P 2014**. "Percezione visiva dei pannelli a messaggio variabile: stima di un modello di previsione dei tempi di lettura"** in "Segnaletica e informazione per il miglioramento della sicurezza" Quaderno n°9 EGAF. ISBN: 978 – 88- 8482 – 566 -7.

Meloni M., Pinna C., Lecca L., Fancello G., Del Rio A. Setzu D., Costa G. and Fadda P 2014. "**Driving Ability Index (DAI) for assessing elderly people's performance**" Advances in Human Aspects of Transportation: Part III, ISBN: 978-1-4951-2099-2 , Neville Stanton, Steve Landry, Giuseppe Di Bucchianico and Andrea Vallicelli

Fancello G., Pinna C. and Fadda P. " **Visual perception of the roundabout in old age",** 19th International Conference on Urban Transport and the Environment, Urban Transport 2013, Wessex Institute of Technology, Kos, Greece, 29 - 31 May, 2013; WIT Transactions on the Built Environments (ISSN: 1746-4498, Digital ISSN: 1743-3509).

Fancello G., Pinna C. and Fadda P. "**Modelos de conducción en los conductores ancianos**" XVI Congreso Argentino de Vialidad y Transito, Cordoba, Argentina, 22-26/10/2012.

Publications

Abbate, C., Luzzatti, C., Vergani, C., 2007. ***Matrix test: speed and accuracy of visual search in aging***. G. Gerontol 55: 11-20.

Anderson SW, Rizzo M, Shi Q, Uc EY, Dawson JD. 2005. ***Cognitive Abilities Related to Driving Performance in a Simulator and Crashing on the Road. Proceedings of the Third International Driving Symposium on Human Factors in Driver Assessment***, Training and Vehicle Design; 2005 Jun 27-30; Rockport (ME). 2005.

Anstey K.J., Horswill M, S., Wood J.M., Hatherly C. 2011. **The role of cognitive and visual abilities as predictors in the Multifactorial Model of Driving Safety,** Accident Analysis and Prevention . 2012 Mar;45:766-74. doi: 10.1016/j.aap.2011.10.006. Epub 2011 Nov 30.

Anstey K. J., Wood J, Lord S, Walker J.G., 2005. **Cognitive, sensory and physical factors enabling driving safety in older adults,** Clinical Psychology Review 25 (2005) 45-65.

Ball, K. Owsley, C., Sloane, M.E., Roenken D.L., 1993. ***Visual attention problems as a predictor of vehicle crashes in older drivers*.** Invest Ophthalmol Vis Sci; 34:3110–23.

Barbaranelli C., D'Olimpio F., 2007. Analisi dei dati con SPSS I Le analisi di base, Edizioni Universitarie di Lettere economia e Diritto.

Barbaranelli C., 2006. Analisi dei dati con SPSS II Le analisi multivariate, Edizioni Universitarie di Lettere economia e Diritto.

Burg, A., 1967. ***The relationship between vision test scores and driving record: General findings***. Report 67-24. Department of Engineering, University of California, Los Angeles.

Burns, P.C., 1999. ***Navigation and the mobility of older drivers***, The Journal of Gerontology, 54 (1), pp. S49–S55.

Butler, K.M., Zacks, R.T., Henderson, J.M., 1999. Suppression of reflexive saccades in younger and ***older adults: age comparison on an antisaccade task***. Memory Cognit, 27(4): 584-591.

Carr DB, Barco PP,Wallendorf MJ, Snellgrove CA, Ott BR. ***Predicting road test performance in drivers with dementia.*** *Journal of the American Geriatrics Society* 2011;**59**(11): 2112–7

Castro, C., Horberry, T., 2004, ***The Human Factors of Transport Signs,*** CRC Press Taylor & Francis Group ISBN: 0-415-31086.

Ciampicacigli R., 2007 .***L'Italia invecchia al volante***, Censis.

Chandraratna S., Michell L., Stamatiadis N., 2002. ***Evaluation of the transportation safety needs of older drivers.*** Dept. of Civil Engineering, University of Kentucky.

Colsher P.L., Wallace R.B., 1993. ***Geriatric assessment and driver functioning***. Clinics in Geriatric Medicine. 1993;9(2):365-375.

Comrey A.L., Lee H. B., 1995. **Introduzione all'analisi fattoriale**, Edizioni Universitarie di Lettere economia e Diritto.

CONSOL – Road safety in the ageing society –, Siren A., Haustein S., Meng A., Bell D., Pokriefke E., Lang B., Medina K.F., Gabaude C., Marin –Lamellet C., Monterde I Bort H., Strnadova Z., 2013 ***Driving Licensing Legislation*** – Final report September 2013 (co-founded by the European Commission).

Crassini B., Brown, B., Bowman, K.,1998. ***Age related changes in contrast sensitivity in central and peripheral retina***. Perception, 17: 315-332.

Crizzle A.M., Classen, S., Uc, E. 2012. ***Parkinson's disease and driving: An evidence based review.*** *Neurology*, 79, 2067-2074.

Daigneault G., Joly P., Frigon J.Y., 2002. **Previous convictions or accidents and the risk of subsequent accidents of older drivers,** Accident Analysis and Prevention, 34, 257-261.

Davis E.T., Fujawa G., Shikano ., 2002. ***Perceptual processing and search efficiency of young and older adults in simple-feature search task: a staircase approach.*** *Psychological Sciences*, Vol.57B: 324-337.

Department of Economic and Social Affairs Population Division of the United Nations, 2013. **World population ageing*; 2013.***

De Raedt R., Ponjaert-Kristoffersen I., 2000. ***The relationship between cognitive/neuropsychological factors and car driving performance in older adults,*** Journal of the American Geriatrics Society

Dewar, R.E., Kline, D.W., Swanson, H.A., 1994***. Age differences in the comprehension of traffic sign symbols***. Transp. Res. Rec., 1456:1-10.

Dewar, R.E., Kline, D.W., Swanson, H.A., 1994. ***Symbol signing design for older drivers***. Final Report. Federal Highway Administration.

Dobbs, B. M., 2005. ***Medical Conditions and Driving: A Review of the Literature***.

Dobbs AR. ***Evaluating the driving competence of dementia patients.*** Alzheimer Disease and Associated Disorders 1997;11 Suppl 1:8–12.

Eby, D.W., Trombley, D.A.,Molnar, L.J., Shope, J.T., 1998. ***The assessment of older drivers' capabilities: a review of the literature.*** UMTRI technical report. Transportation research Institute, Université du Michigan, Ann Arbor, États-Unis.

Eby, D.W., 2007***. Development and pilot testing of an assessment battery for older drivers.***

European Transport Safety Council, 2010. ***Preventing Road Accidents and Injuries for the Safety of Employees*** – Fitness to drive.

Evans, L. (1991). **Traffic Safety and the Driver**. New York, NY: Van Nostrand Reinhold.

Fancello, G., Stamatiadis N., Pani E., Fadda P.,Wilkinson, 2008. **Are Older Drivers different in the Us And Italy?,** "Urban Transport XIV" Conference Proceedings.

Ficke, R. 2003. **Aging and Disability: Implications for Transportation Research**. Paper presented at the Transportation Research Board Annual 2003.

Fonda, S. J., Wallace, R. B. & Herzog, A. R., 2001. **Changes in driving patterns and worsening depressive symptoms among older adults**. Journal of Gerontology: Social Sciences, 56, 343–351.

Freund B.,∗, Colgrove L., Burke B., McLeod R., 2005, **Self-rated driving performance among elderly drivers referred for driving evaluation**, Accident Analysis and Prevention 37 (2005) 613–618

Gabaude ., 2003. ***Exploration of the visual and attentional abilities of elderly drivers Benefits and techniques***, Recherche Transports Securite, Volume 81, October 2003, pp. 165-176(12).

Gabrieli JDE, Brewer JB, Vaidya CJ. Memory. In: Goetz CG, Pappert EJ, eds. 2003, ***Textbook of Clinical Neurology***, 1st Ed. W.B. Saunders Company, 1999:56-69. Available at: http://www.mdconsult.com. Accessed January 23.

Galski, T. , Bruno, RL and Ehle, HT 1992. ***Driving after Cerebral Damage: A Model with Implications for Evaluation*.** Am. J. Occup. Ther. **Vol. 46** , pp. 324-332.

Galski T, Bruno RL, Ehle HT. 1993. ***Prediction of behind-the-wheel driving performance in patients with cerebral brain damage: a discriminant function analysis.*** Am J Occup Ther. 1993 May;47(5):391-6.

Guerrier, J.H., Manivannan, P., Nair, S., 1999. ***The role of working memory, field dependence, visual search, and reaction time in the left turn performance of older female drivers***. Applied Ergonomics, 30, 109–119, 1999.

Hakamies-Blomqvist L., 2004. ***Older drivers – a review***, VTI rapport 497a.

Hakamies-Blomqvist L., Anu Siren 2003. ***Deconstructing a gender difference: Driving cessation and personal, driving history of older women*** Journal of Safety Research 34 (2003) 383– 388.

Hakamies-Blomqvist, L, Johansson, K & Lundberg, C. 1996. ***Medical screening of older drivers as a traffic safety measure – a comparative Finnish-Swedish evaluation study***. Journal of the American Geriatrics Society. 44: 650-653

Hasher, L., Zacks, R.T., 1988.***Working memory, comprehension and aging: a review and a new view***. In: Bower, G.H. (Ed.), The psychology of learning and motivation, Vol. 22. Academic Press, NewYork, États-Unis, pp. 193–225.

Hauer, E. 1988. ***The safety of older persons at intersections.*** *Special Report 218: Transportation in an Aging Society: Improving Mobility and Safety for Older Persons*, Volume 2. Washington, DC: Transportation Research Board.

Hatakka, M., Keskinen, E., Gregersen, N. P., Glad, A. & Hernetkoski, K. 2002. ***From control of the vehicle to personal self-control; broadening the perspectives to driver education***. Transportation Research, Part F, 201-215.

Hills, B.L., 1980, **Vision, visibility and perception in driving**. Perception, 9, 183-216.

Holland, C.A. 2001 ***Older Drivers: A review***. DfT Research Report No.25, http://www.dft.gov.uk/stellent/groups/dft_rdsafety/documents/page/dft_rdsafety_504602.hcsp

Hu P.S., Trumble D.A., Foley D.J., Eberhard J.W., Wallace R.B. 1998. ***Crash risks of older drivers: A panel data analysis***, Accident Analysis and Prevention, 30 (1998), pp. 569–581

International Ergonomics Association. ***What is Ergonomics***. Website. Retrieved 17 March 2014.

Ivers R.Q., Mitchell P., Cumming R.G., 1999. ***Sensory impairment and driving: The Blue Mountains Eye Study,*** American Journal of Public Health, 89 (1999), pp. 85–87.

Jang, R.W., Man-Son-Hing M, Molnar F.J., Hogan D.B., Marshall S.C., Auger J, Graham I.D., Bitensky N.K., Tomlinson J., , Kowgier M.E., Naglie G., 2007, ***Family Physicians' Attitudes and Practices Regarding Assessments of Medical Fitness to Drive in Older Persons.***

Janssen, W.H., 1979. ***Routeplanning en geleiding: Een Literatuurstudie***. Report IZF 1979 V.13. Soesterburg: Institute for Perception TNO, Holland.

Justiss M., 2005. ***Development of a behind-the-wheel driving performance assessment for older adults***, PhD Thesis, University of Florida.

Kim, T., Oh C., Yeon J.Y., Kim, S., 2009. ***Estimation of message reading time for Variable Message Signs,*** Dept. of Advanced Transportation Research, The Korea Transport Institute, 88th Annual Meeting of the Transportation Research Board (TRB), Washington.

Klein DC, Coon SL, Roseboom PH, Weller JL, Bernard M, Gastel JA, Zatz M, Iuvone PM, Rodriguez IR, Bégay V, Falcón J, Cahill GM, Cassone VM, Baler R. ***The melatonin rhythm-generating enzyme: molecular regulation of serotonin N-acetyltransferase in the pineal gland***. Recent Prog Horm Res. 1997;52:307-57;

Kline, D.W., Scialfa, C.T., ***Sensory and perceptual functioning: basic research and human factors implications***, 1997.

Li, G.H., Braver, E.R., & Chen, L.H., ***Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers***. Accident Analysis and Prevention, 35: 227–235, 2003.

Langford J, Methorst R, Hakamies-Blomqvist L., ***Older drivers do not have a high crash risk--a replication of low mileage bias,*** 2006

Lee H. C., Cameron D., Lee A.H., 2003. ***Assessing the driving performance of older adult drivers: on-road versus simulated driving***, Accident Analysis and Prevention, 35, 797-803.

Lyman S., Ferguson S. A., Braver E. R, Williams A. F., 2002, **Older driver involvements in police reported crashes and fatal crashes: trends and projections,** Injury Prevention, 8:116–120.

Margolis, K. L., Kerani, R. P., McGovern, P., Songer, T., Cauley, J. A., & Ensrud, K. E. 2002. ***Risk factors for motor vehicle crashes in older women***. The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 57(3), M186−M191.

Marottoli, R. A., Richardson, E. D., Stowe, M. H., Miller, E. G., Brass, L. M., Cooney Jr., L. M., et al. 1998. ***Development of a test battery to identify older drivers at risk for self-reported adverse driving events***. Journal of the American Geriatric Society, 46, 562–568.

Marshall S.C., 2011, **The Role of Reduced Fitness to Drive Due to Medical Impairments in Explaining Crashes Involving Older Drivers**, Traffic Injury Prevention, 9: 4, 291-298.

Martin A.J., Marottoli R, O'Neill D. 2013. ***Driving assessment for mantaining mobility and safety in drivers with dementia (Review)***. The Cochrane Collaboration 2013. http://thecochranelibrary.com – Wiley.

Massie, D. L., & Campbell, K. L. 1993. ***Analysis of Accident Rates by Age, Gender, and Time*** *of Day* Based on the 1990 Nationwide Personal Transportation Survey. Report No. UMTRI-93–7. Ann Arbor, MI: University of Michigan Transportation Research Institute.

Maycock, G. 1997. ***The Safety of Older Car Users in the European Union***. Basingstoke, UK: Foundation for Road Safety Research.

McGwin G Jr, Sims RV, Pulley L, Roseman JM, 2000. ***Relations among chronic medical conditions, medications, and automobile crashes in the elderly: a population-based case-control study***, American journal of epidemiology, 2000 Sep 1;152(5):424-31.

McKnight J. A., McKnight S.A., ***Multivariate analysis of age related driver ability and performance deficits***, Accident Analysis and Prevenction, 1999.

Metzner, J.L., Dentino, A.N., Godarrd, S.L., Hay, L.H., Linnoila, M., 1993. **Impairment of driving and psychiatric illness**, Journal of Neuropsychiatry, 5, pp 211-220.

Naumann R. B., Dellinger A.M., Kresnow M., 2011. ***Driving self-restriction in high-risk conditions: how do older drivers compare to others?.*** *Journal of safety research* 42: 67-71.

Odenheimer, G. L., Beaudet, M., Jette, A. M., Albert, M. S., Grande, L., & Minaker, K. L. 1994. ***Performance-based driving evaluation of the elderly driver****: Safety*, reliability, and validity. Journal of Gerontology: Medical Sciences, 49, M153–M159.

Owsley, C. Ball, K., 1991. ***Identifying correlates of accident involvement for the older driver.*** Human Factors, 33, 583-595, 1991.

Owsley C., B.T. Stalvey, J. Wells, M.E. Sloane, G. McGwin Jr., 2001. ***Visual risk factors for crash involvement in older drivers with cataract,*** Archives of Ophthalmology, 119 (2001), pp. 881–887

Owsley C., Stalvey B.T., Phillips J.M., 2003. ***The efficacy of an educational intervention in promoting self-regulation among high-risk older drivers***, Accident Analysis and Prevention, 35, 393-400.

Parker D.; McDonald L.; Rabbit P; Sutcliff P., 2003.***Older drivers and road safety: the acceptability of a range of intervention measures***, Accident analysis and prevention, vol.35, n 5,pp.805-810.

Peraaho M., Keskinen E., Hatakka M., 2003. ***Driver competence in a hierarchical prospective; implications for driver education***. University of Turku, Traffic Research.

Ranney, T. 1994. ***Models of driving behavior: A review of their evolution***, Accident Analysis & Prevention, Vol. 26, 733-750.

Rothengatter, T. 1997. ***Editorial preface***. Applied psychology, Vol. 46 (3), 221-222.

Sims R.V., McGwin G. Jr., Allman R.M., Ball K., Owsley C., 2000. ***Exploratory study of incident vehicle crashes among older drivers***; Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 55 (2000), pp. M22–M27

Sims R.V., Owsley C., Allman R.M., Ball K., Smoot T.M., 1998. ***A preliminary assessment of the medical and functional factors associated with vehicle crashes by older adults,*** Journal of the American Geriatrics Society, 46 (1998), pp. 556–561

Siren A, Hakamies-Blomqvist L. 2005. ***Sense and sensibility. a narrative study of older women's car driving.*** *Transportation Research Part F: Traffic Psychology and Behaviour* 8(3).

Sivak, M., 1996. ***The information that drivers useis it indeed 90% visual?,*** Perception, 25, pp. 1081–1089, 1996.

Sekuler, R., & Ball, K. 1986. **Visual localization: age and practice**. *Journal of the Optic Society of America*, 3, 864-867.

Skyving M., Berg H.Y., Laflamme L., 2009. ***Older drivers'involvement in fatal RTCs. Do crashes fatal to them differ from crashes involving them but fatal to others?.*** *Safety Science*, 47: 640-646

Sommer, M., Arendasy, M., Hansen, H.-D., & Schuhfried, G. 2005. ***Personalauswahl mit Hilfe von statistischen Methoden*** der Urteilsbildung am Beispiel der Flugpsychologie. Untersuchungen des Psychologischen Dienstes der Bundeswehr, 40, 39-64.

Staplin, L., Lococo, K. & Byington, S. 1998 ***Older Driver Highway Design Handbook.*** FHWA-RD-97-135.Department of Transportation, Federal Highway Administration, Washington, DC.

Staplin, L., Lococo, K. H., Gish, K. W., Decina, L.E. 2003. ***Model Driver Screening and Evaluation*** *Program. Volume 2: Maryland Pilot Older Driver Study.* Washington, D.C.: National Highway and Traffic Safety Administration. Retrieved October 15, 2003

Stav B. W., Justiss D.M., McCarthy P.D., Mann W.C, Lanford N.D., ***Predictability of clinical assessments for driving performance***, Journal of Safety Research 39, 2008.

Stutts J.C., Stewart J.R., Martell C. 1998. ***Cognitive test performance and crash risk in an older driver population***. Accident Analysis and Prevention, 30 (1998), pp. 337–346

Thorslund B., Peters B., Lidestam B., Lyxell B., 2013. ***Cognitive workload and driving behaviour in persons with hearing loss***, Transportation research Part F, Volume 21, November 2013, Pages 113–121.

Tuomi K, Ilmarinen J, Jahkola A, Katajarinne L, Tulkki A. 1998. ***Work Ability Index (2nd Edition)***. Helsinki: Finnish Institute of Occupational Health.

Vaa, T., 2003***. Impairment,diseases, age and their relative risks of accident involvement: Results from meta-analysis***, 2003.

Vaux LM, Ni R, Rizzo M, Uc EY, Andersen GJ. ***Detection of imminent collisions by drivers with Alzheimer's disease and Parkinson's disease: a preliminary study***. *Accident; Analysis and Prevention* 2010;**42**(3):852–8.

Weihong Guo A., Blythe P., Edwards S., Pavkova K., Brennan D., 2013, ***Effect of intelligent speed adaptation technology on older drivers' driving performance,*** IET Intelligent Transport Systems, doi: 10.1049/iet-its.2013.0136.

Wood, J. 2002. ***Age and visual impairment decrease driving performance as measured on a closed-road circuit***. Human Factors, 44, 482-494.

Legislation

Directive 2006/126/EC of the European Parliament and of the Council of 20 December 2006 on driving licences.

Commission Directive 2009/113/EC of 25 August 2009 amending Directive 2006/126/EC of the European Parliament and of the Council on driving licences.

Sitography

http://ec.europa.eu/transport/road_safety/users/eldery-drivers/index_en.htm

http://www.polisonnografia.it/disturbi_anziano.php

http://www.ncbi.nlm.nih.gov/pubmed/9238858

http://w3.uniroma1.it/chemo/heritage/correlazione/rslide33.html

http://www.dica33.it/terza-et%C3%A0-patologie/terza-et%C3%A0-00197.htm

http://www.neuropsicologia.it/content/view/78/90/

http://it.wikipedia.org/wiki/Mini_Mental_State_Examination

http://www.transport- research.info/web/projects/project_details.cfm

http://ec.europa.eu/transport/road_safety/users/eldery-drivers/index_it.htm

http://www.iapb.it/news2.php?id=772

http://ec.europa.eu/transport/road_safety/users/eldery-drivers/index_it.htm

http://www.alz.org/aaic/ (Alzheimer's Association)

http://www.cieca.eu/template_page.asp?pag_id=32&lng_iso=EN (International commission for driver testing)

http://en.wikipedia.org/wiki/Factor_analysis.

Driving Ability Index

1. Occupation: _____ Age _____ Gender _____
2. Education:
   - **a.** No qualification
   - **b.** GCSE/O level and equivalents
   - **c.** A levels and equivalents
   - **d.** University degrees
3. Smoking: **a.** No (go to Q6) **b.** Ex-smoker (go to Q6) **c.** Yes (go to Q5)
4. If you answered "yes" to Q4, how many cigarettes do you smoke on a typical day? _____
5. How often do you have a drink containing alcohol? Please tick ONE only.
   - **a.** Never
   - **b.** Monthly or less
   - **c.** 2 to 4 times a month
   - **d.** 2 to 3 times a week
   - **e.** 4 or more times a week
6. How many units of alcohol do you drink on a typical day when you are drinking? Please tick ONE only (* one pint of beer or a medium size glass of wine is about 2 units).
   - **a.** 1 or 2 units
   - **b.** 3 or 4 units
   - **c.** 5 or 6 units
   - **d.** 7 to 9 units
   - **e.** 10 or more units
7. How satisfied are you with the quality and amount of sleep you get?

   From 5 "Very satisfied" to 1 "very unsatisfied" 1 2 3 4 5
8. Approximately how many miles do you drive on a typical day? _____
9. Approximately how many miles do you drive in a typical year? Please tick ONE only.
   - **a.** 0-2,000
   - **b.** 2,001-5,000
   - **c.** 5,001-8,000
   - **d.** 8,001-10,000
   - **e.** 10,001+

   What portion of your annual mileage is urban driving _____%

   What portion of your annual mileage is interurban driving_____%
10. How often do you drive? Please tick ONE only.
    - **a.** Occasionally (a few days a year but less than one day a month)
    - **b.** Sometimes (a few days a month but less than one day a week)
    - **c.** Often (one or two days a week)
    - **d.** Very often (3 or more days a week)
11. How often do you travel with other people?

    a. Never **b.** Occasional **c.** Sometimes **d.** Most of the time **e.** All the time

12. Are you usually the main driver or the passenger when travelling with others?

a. Main driver **b.** Passenger

13. What is the engine size of your everyday vehicle? Please tick ONE only.

a. Less than 1.0L **c**. 1.4-1.6L **e**. 2.0L+

b. 1.0-1.3L **d**. 1.7-1.9L

14. Year of manufacture of your car _____

15. Do you have any **driving qualifications** other than the standard DSA driving test?

If yes, please specify:

_____

16. Have you ever driven the following vehicles? Please tick ALL that apply.

a. Motorbike **c**. Van/mobile home/minibus **e.** Ambulance/Fire Engine

b. Sports car **d**. Lorry/bus/Coach

17. Have you been involved in any road traffic accidents/collisions in the past 5 years? Please tick ALL that apply

a. No **c**. Yes with damage to property only

b. Yes with injury to people (e.g. driver, passenger, pedestrian, or cyclist).

18. Have you ever been caught committing a driving offence? Please tick ONE only.

a. Never **c**. within the past 12 month

b. b. more than 12 months ago **d**. within the past 30 days

if you have choose **b**, **c** or **d**, please give the details of the offence: _____

_____

19. How do you rate your current driving skills refers to 'your best period of life?

0 1 2 3 4 5 6 7 8 9 10

*A response of '**0**' means 'totally unable to drive'.

*A response of '**10**' means 'your peak driving performance'.

20. How do you rate your current driving ability in relation to your physical conditions?

1	2	3	4	5
Very poor	Quite poor	Average	Quite good	Very good

21. How do you rate your current driving ability in relation to your mental capability?

1	2	3	4	5
Very poor	Quite poor	Average	Quite good	Very good

22. Please indicate, from the following list, any illness or disorder that you suffer now diagnosed by a doctor. Please tick ALL that apply. Or simply specify the number of problems in each given category if you prefer not to answer this question.

Muscular-skeletal complaints

- ❑ neck problems, recurrent pain
- ❑ lower back problems, recurrent pain
- ❑ sciatica
- ❑ problems with limbs, recurrent pain
- ❑ arthritis
- ❑ total number of problems in this category: _____

Cardiovascular diseases

- ❑ hypertension (high blood pressure)
- ❑ coronary diseases chest pain during exertion (angina pectoris)
- ❑ coronary thrombosis
- ❑ cardiac insufficiency
- ❑ total number of problems in this category: _____

Respiratory disorders

- ❑ frequent infections of respiratory tract
- ❑ chronic bronchitis/emphysema
- ❑ chronic sinusitis
- ❑ bronchial asthma
- ❑ obstructive sleep apnoea syndrome
- ❑ pulmonary tuberculosis
- ❑ total number of problems in this category: _____

Mental, nervous and sensory system

- ❑ mental illness or problem (depression, anxiety, insomnia)
- ❑ hearing loss or ear damage
- ❑ eye problems (cataract / glaucoma)
- ❑ neurological disorders (ictus, neuralgia, migraine, epilepsy)
- ❑ total number of problems in this category: _____

Digestive disorders

- ❑ liver stones or gallbladder disorders
- ❑ liver or pancreas diseases
- ❑ gastric or duodenal ulcers,
- ❑ gastritis, colitis, irritable bowel
- ❑ total number of problems in this category: _____

Genitourinary disorders

- ❑ urinary infections
- ❑ kidney disease
- ❑ genital disorders (inflammation of ovaries or prostate)
- ❑ total number of problems in this category: _____

Skin complaints

- ❑ allergies/eczema
- ❑ other rashes, or skin complaints
- ❑ total number of problems in this category:_ _____

Tumours

- ❑ benign tumour
- ❑ malignant tumour (cancer)
- ❑ total number of problems in this category:_ _____

Endocrine and metabolic disorders

- ❑ obesity
- ❑ diabetes
- ❑ goitre or other thyroid disorders
- ❑ total number of problems in this category: _____

Blood disorders

- ❑ anaemia
- ❑ other blood disorders
- ❑ total number of problems in this category:_

Other illnesses/disorders, please specify: _____

- ❑ None of the above
- ❑ I prefer not to answer this question.

23. Do your current health conditions make it difficult to drive?

    a. I feel I am no longer able to drive
    b. I feel I am only able to drive for short distances
    c. On average I drive slower than I used to.
    d. I am able to drive, but it's getting difficult
    e. I do not have any difficulties

24. Have you had to stop driving due to health problems during the past 12 months? Please tick ONE only.

    a. Not at all **b**. <10 days **c.** 10-24 days **d.** 25-99 days **e**. 100+ days

25. Have you ever stopped driving for longer than 3 months since you got your full driving license?

    a No **b**. Yes. Please specify how long and the reason _____

26. Do you believe, given your current health conditions, that you will be able to continue driving over the next two years? Please tick ONE only.

    a. Highly unlikely **b.** Not sure **c**. Maybe **d.** Definitely

27. How often do you wear your seat belt when driving? Please tick ONE only.

    a. Never **b**. Sometimes **c.** Most of the time **d.** Always

28. Are you undergoing any treatment that affects your alertness?

    a. No **b**. Yes

29. Have you ever fallen asleep behind the wheel?

    a. No **b**. Yes

30. How often do you use your rear view mirror?

    a. Never **b**. only before making particular manoeuvres **c.** every few minutes

31. Do you often see the road signs at the last minute?

    a. No **b**. Yes

32. Have you given up driving at night?

    a. No **b**. Yes

33. If you have answered 'No' to Q32, please indicate how you feel about driving at night.

Do you worry about merging into traffic?	Never	Sometimes	Often	Always
Do you feel stressed or get nervous?	Never	Sometimes	Often	Always
Do you feel that the roads are not sufficiently lit?	Never	Sometimes	Often	Always
Do you have difficulty seeing or understanding road markings?	Never	Sometimes	Often	Always
Do you have to slow down to read the road signs or street names?	Never	Sometimes	Often	Always

THANK YOU!