Tuning highways for future use: the role of the elderly driver

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Abstract

In 2060, 40\% of the Dutch population will be 65 years or older. A growing number of these elderly drivers will continue to make use of the road. Rijkswaterstaat has conducted a survey of facilities that can assist elderly drivers while using the road. Based on a literature study and a micro simulation (with Aimsun), research was conducted into the impact of the increasing number of elderly drivers with regard to traffic flows and traffic safety. In the Aimsun simulations, the 'greying' situation was compared to a reference situation, whereby the number of traffic lanes, the traffic intensity and the percentage of trucks were entered as variables. This analysis raises questions if we look closely at specific manoeuvres, such as the merging manoeuvre. This often involves questions of a psychological nature, and mainly questions relating to 'human factors'. Results of the study support the hypothesis that creating additional time and space for and by elderly drivers to perform the driving task will have a positive impact on both traffic flows and the safety of the traffic system.

Keywords: Elderly drivers; future scenario; micro simulation Aimsun; human factors.

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1. Introduction

The Dutch population is ageing. An ever larger part of the population is growing older than 65 years. According to the current forecasts, this trend will continue to increase until around 2060. The population size will then decrease, however the increase in life expectancy is expected to continue after this period (Van Duin et al., 2012; Garssen, 2011).

People in nearby future will work and participate longer in all kinds of social, cultural and recreational activities. It is no surprise that people older than 65 years of age are responsible for almost half of the increase in mobility (between 1995 and 2010). This is not only an effect of the growth of the population of 65 years and older, but also an effect of changing mobility patterns of the elderly (Planbureau voor de Leefomgeving, 2013). With people becoming older the question rises up to what age elderly will be physically and mentally fit enough to drive and participate in traffic. This age varies per person. We have to realize that if one person with the age of 80 years is fit enough to participate in traffic, it doesn’t mean that all people of 80 years will be.

This article examines what the consequences of the above-mentioned developments could be in terms of road usage, particularly for highways that are managed by Rijkswaterstaat, the Dutch Directorate-General for Public Works. From this perspective: is the highway network ready for the future?

‘The future’ is pointing towards an increase in elderly drivers. However, more and other changes are also expected. Experience and evaluation studies have taught us that predicting the future is extremely difficult, if not impossible. To understand just how much the world has changed simply look back a few decades. Mobile telephony, Internet and ‘social media’ have had a huge impact. Back in the 1980s, facilities such as these were hardly or not available. The use of this media has an enormous impact on the mobility behaviour of young people, but also on the application of traffic management measures (Van der Waard et al., 2013; Immers et al., 2013; KiM Mobility Report (KiM Mobiliteitsbalans), 2013; TrafficQuest, 2014). This document presents the results of an analysis of the potential effects of an ageing Dutch population on the use and design of the highway network.

2. More elderly drivers on the road: what does this mean?

To anticipate on the future sketched above Rijkswaterstaat conducted a general survey of facilities that can assist elderly drivers while using the road (Rijkswaterstaat, 2010; Van Doorn et al., 2011). So far traffic itself was not taken into account in the evaluation of these facilities. Therefor in this paper the main question is:

What could an increase in the number of elderly drivers (65+) on highways mean for the traffic situation?

Does an ageing population have an impact on traffic flow and/or road safety? And are these positive effects (for example, is it true that the higher the number of elderly drivers, the calmer it is in traffic) or negative (whereby the interaction between elderly drivers and other road users has an impact on undesired road behaviour)? The complexity of the situation and uncertainty of the future make it impossible to provide an immediate answer. Even though the ambitions of the desired analysis may be high, in the practice of the traffic engineering research, we can ‘only’ work with what we are given. In addition to studies of the existing literature (SWOV, 2010, 2012; Vlakveld et al., 2011; Friso et al., 2010; Brouwer, 2005; Withaar, 2000) we have used micro traffic simulation. The advantage of this approach is that the results are better adaptable in the day-to-day focus on management and maintenance. The drawback of a traffic-engineering model is that the results are largely determined by the model characteristics themselves. From a psychological perspective, the described increase in elderly drivers must also be placed in a framework. How many drivers does this concern, now and in the future? What speeds do these elderly drivers drive? How do they respond to other traffic in terms of reaction time, but also, for example, to the composition of the traffic such as, more or less heavy good vehicles? Which traffic lanes (right, centre, left) do elderly drivers prefer to use? And most importantly, how will they respond to new technology that will be available?
It is clear that these main questions lead to numerous other questions. For the moment, not all these questions shall or can be examined; this calls for further steps in the desired studies.

3. Approach

The Aimsun simulation model was used in this study. In Aimsun every vehicle is simulated individually (and visualised) whereby the vehicle is assigned individual driving characteristics (origin, destination, desired driving speed, overtaking behaviour, etc.). The traffic demand is time dependent. The duration and route of each movement is dependent on different traffic conditions.

Aimsun can be used to identify multiple categories of road users with different behavioural characteristics. Different physical characteristics of the vehicle and behavioural characters of the driver are defined per category; whereby, in addition to the average value, other variations can also be indicated. In this way, the Aimsun model makes it possible to implement, simulate and analyse the driving behaviour of elderly drivers (‘senior vehicle behaviour’), divided into one or more categories. The vehicle and driver characteristics concern the following aspects:

- The desired speed in relation to the speed limits and speed acceptance;
- The general reaction time and headway to other vehicles;
- Estimate of a safe margin with regard to giving priority and changing lanes;
- Behaviour with regard to accelerating and braking at traffic lights, in priority situations, on multilane roads and intersections, (keeping right) during overtaking and merging manoeuvres, high or higher traffic intensities, during bad weather / poor visibility, etc.:
- Driving behaviour during (temporarily) altered traffic situations, for example road works (smaller lanes, chicanes, etc.) and alternative routes (search/viewing behaviour, acceptance of traffic information, etc.);
- Flexibility with regard to the choice of route, responding to traffic information (fixed and variable), etc.

Based on a literature scan and consultation with experts, the following assumptions were made. In 2025, around 25% of the population will be over the age of 65. And in 2025, 20% of the car driving population will be referred to as ‘senior’, which implies that different driving characteristics apply to this group. These include mild to moderate disabilities, problems with divided attention and longer reaction times. This estimate in combination with the current knowledge regarding the behaviour of senior drivers has led to the following starting points for the micro simulations.

Population

In the micro simulations, a distinction was made between two populations of travellers:

Population 1: refers to the current traffic composition. Simulations with this group are referred to as the reference condition.

Population 2: refers to a situation in the future whereby more elderly people will be driving on the highways. Simulations that were run with this group are referred to as the senior condition. It should be noted that in the case of the reference condition, seniors, with all their diverse characteristics, take part in traffic in an implicit way. These characteristics of elderly drivers are made explicit in the senior condition that describes the future situation.

The group of seniors has the following composition: 80% reference group and 20% seniors. Seniors are divided into two groups according to the nature of their limitation:

- 12% are referred to as ‘seniors with mild disabilities’.
- 8% are referred to as ‘seniors with moderate disabilities’.

In the reference condition and senior condition, the settings differ for the following model parameters:

- Speed acceptance: speed acceptance refers to the desired speed as a factor of the maximum speed. A value of 0.8 and a maximum speed of 100km/h means that the person will be inclined to drive at 80 km/h.
- Response factor: the response factor indicates ‘how reactive the driver is driving’. To what extent does the driver keep his distance from a vehicle in front, and how big should the gap be before a driver initiates a merging or overtaking manoeuvre. The higher the factor, the more space (time) the driver will need.
- Reaction time: reaction time is the amount of time that passes before a vehicle ‘moves’ (takes a follow-up action).
• Position on the road: preferred position on the road (driving on the left, median or right lane).
Table 1 shows the parameter values that were applied in the different simulations.

Table 1. Parameter settings of simulations

<table>
<thead>
<tr>
<th></th>
<th>Reference group 80%</th>
<th>Mildly disabled seniors 12%</th>
<th>Moderately disabled seniors 8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed acceptance</td>
<td>1.1</td>
<td>1.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Response factor</td>
<td>1.0</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Reaction time</td>
<td>0.75</td>
<td>1.0</td>
<td>1.25</td>
</tr>
<tr>
<td>Position on the road</td>
<td></td>
<td></td>
<td>Preferably right lane (except trucks)</td>
</tr>
</tbody>
</table>

**Simulation variants**

Based on practical considerations, the choice was made to simulate the following combinations of traffic and infrastructure characteristics:

**Infrastructure**

The design variants are:

1. Acceleration and deceleration lane of 200 metres each, main carriageway with 2 traffic lanes; additionally a variant with an acceleration and deceleration lane of 400 metres each (see Figure 1);
2. Peak hour traffic lane with a single acceleration and deceleration lane - main carriageway with 2 traffic lanes (see Figure 2);
3. Peak hour traffic lane with a single acceleration and deceleration lane - 3 traffic lanes main carriageway;
4. Weaving section consisting of 2 + 2 traffic lanes (see Figure 3).

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![Fig. 1. Acceleration and deceleration lane of 200 metres each, main carriageway with 2 traffic lanes.](image)

![Fig. 2. Peak-hour traffic lane with a single acceleration and deceleration lane; main carriageway with 2 traffic lanes.](image)

![Fig. 3. Weaving section consisting of 2 + 2 traffic lanes.](image)

The variants were evaluated at three locations on the theoretical road network: when merging and when driving straight on or respectively weaving. Each simulation lasted one hour. The results are described per design variant. The reference condition and the senior condition are compared against each other.

Two flow-capacity variants are simulated in each design variant:

1. Heavy traffic (determined on the basis of around 90% of the maximum capacity of the weaving section);

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1Variants and manoeuvres were chosen that were expected to show the greatest impact from an increase in the number of seniors. The simulation results prove insight in the driving behavior and the performance of the network, but we also recommend performing some in-depth studies addressing specific manoeuvres as well as deploying longer simulation runs.
2. Off-peak traffic (determined on the basis of around 75% of the maximum capacity of the weaving section).

To map the capacity of a road section, the traffic demand was gradually increased. The next step consisted of mapping the amount of traffic that drove along the road section. This gives an indication of the amount of traffic that is processed before congestion occurs.

To model the influence of truck traffic the quantity of truck traffic was varied. The following two variants were simulated (for both flow-capacity variants):

1. High intensity of heavy goods vehicles (15% truck traffic);
2. Low intensity of heavy goods vehicles (5% truck traffic).

4. Results of the micro simulations

The model results were examined on the basis of the speeds, densities, travel times, etc. that the model generated, the screen shots of traffic in different situations (see Figure 4) and time-road diagrams (see Figure 5).

Fig. 4. Screen shot from the simulation: merging problems.

Fig. 5. Time (y-axis)-road (x-axis) diagrams main carriageway design variant 1: high traffic intensity and heavy truck traffic.

The results from the different model simulations are described with regard to the traffic flow on the main carriageway and the quality of the traffic flow per different manoeuvre (merging, exiting, weaving).

Traffic flow

The main changes to the traffic situation, with a comparison between the reference condition and senior condition, are:

If traffic is calm (around 70% of the maximum capacity) and there is hardly any truck traffic (5%), there are hardly any differences between the conditions. At the simulated locations (merge, exit and peak-hour traffic lane) the average speed on the main carriageway decreases slightly. In both conditions, road users drive more slowly. Adding a large number of elderly drivers to the traffic has no negative effect on these traffic conditions.

If the capacity on the road is under pressure, the traffic situation will change in both conditions. For example, this is the case at the merge location of a 2-lane main carriageway (variant 1) and the exit location after a peak-hour traffic lane (variant 2). In both situations the speed is adjusted downwards, the effect is greater in the senior condition. In these situations, the capacity pressure will increase if seniors are added; this causes more ‘shock waves’ in the traffic. This is mainly the case if there is heavy truck traffic.

As laid down in ‘Handboek Capaciteitswaarden Infrastructuur Autosnelwegen 2011’, the manual for capacity values highway infrastructure.
The senior condition, with a lot of (truck) traffic, leads to more delays on the 2-lane road than on the 3-lane road. This is due to the fact that merging (accelerating) on a 2-lane road is more difficult than on a 3-lane road, but drivers on the main carriageway can create more space for merging traffic on the right lane. This is why in the 3-lane situation elderly drivers will have more time to perform the manoeuvre.

If traffic jams occur at a certain location, the simulations show that in the senior condition the likelihood that the traffic flow will resume to normal is lower than in the reference condition. Traffic disruptions are solved faster in the reference condition.

At locations where complex manoeuvres are required, such as complex lane changes and weaving, this results in more turbulence in the traffic flow. This mainly leads to disruptions in the senior condition. We recommend to conduct further research at these locations, for example by performing behavioural observations.

Results per manoeuvre: merging, exiting and weaving

**Merging**
Senior drivers use more time to merge because of lower merging speeds. They also desire larger gaps in the traffic flow and they respond more slowly to changes in the flow.

The simulation shows that, if the traffic intensity is high, merging senior drivers will drive more slowly, or even come to a standstill on the acceleration lane. This could result in a ‘queue’ behind the elderly driver who is attempting to merge. This creates a more turbulent traffic situation at that location and under these conditions than in the situation where it is quiet on the road. A clear example of this effect can be seen in the simulations in design variant 1 (acceleration lane, 2-lane road). In the senior condition, the traffic density and high percentage of trucks result in lower speeds on the main carriageway (see Figure 5).

Does this phenomenon have an impact on traffic safety? It is difficult to establish this link, but it assumed that any disruption to traffic will increase the likelihood of an incident. It is also known that significant differences in speed between and within drivers do not contribute towards traffic safety. The risk is increased because any disruption will require action on the part of the driver. Mistakes are more likely to occur in this situation.

Because of the increased likelihood of mistakes, in theory there is a higher probability of head-on collisions (for example as a result of differences in speed) or side collisions (unexpected evasive manoeuvres). The simulations of the different design variants show that, in the senior condition, turbulence can be prevented if merging traffic is not forced to switch lanes (in variants with a peak-hour traffic lane). However, the problem still occurs if the peak-hour traffic lane is closed.

**Exiting**
A second safety critical task concerns exiting. In this case, the simulations also showed that traffic problems could arise in various situations. Part of the elderly drivers will tend to leave the centre lane (applies to variants with a peak-hour traffic lane). This means that a lane change is needed: (truck) traffic (not exiting) also needs to change lane (from the peak-hour traffic lane to the centre lane), and exiting traffic must move one lane to the right. These manoeuvres are complex if there is a lot of (truck) traffic on the road. This task also has to be executed under time pressure. This can lead to traffic disruptions, mainly if the percentage of elderly drivers is high. This disruption can also increase the safety risk.

**Weaving**
The processing of information in combination with timely action, could prove to be a difficult point for elderly drivers on the road. Time pressure plays a role in the last design variant, the weaving section. In the simulations with the weaving section, the elderly driver was free to determine where he wanted to drive. The simulation results show that the traffic uses the entire weaving section to presort for their exit. This ensures that the traffic situation is fairly calm in the weaving section. In the senior condition, there is some turbulence at the end of the weaving section. This is due to the fact that relatively many senior drivers prefer not to drive on the left lane because they generally maintain a lower speed than other drivers, and do not want to frequently change lanes. This results in a situation whereby drivers that want to change lanes at the very last moment are unable to find a sufficiently large gap.

An important question here is how the senior driver will perform this weaving or exit task? Will drivers perform the weaving manoeuvre as fast as possible or will they postpone the lane change until they nearly reach the end?
of the weaving section? This question remains unanswered and should be looked into. The fact whether or not the elderly driver is familiar with the situation is an important compensating factor here. Performing the weaving task is easier if the driver is familiar with the situation. If the driver is able to understand the situation, he/she will be better able to anticipate and will feel less pressure.

5. More detailed explanation of the ‘merging’ manoeuvre

The micro simulations show that merging situations, weaving situations and exit situations with a peak hour traffic lane also demand the drivers’ attention as a result of the traffic flow. The presented results are based on calculations, but what do elderly drivers think about this? According to interviews with elderly drivers, we know that the merging manoeuvre, in particular, demands a great deal of attention from them: elderly drivers frequently indicated that they considered the merging manoeuvre on highways a difficult manoeuvre (Ying, 2010; Dijksterhuis et al., 2012).

One option to facilitate elderly drivers would be to extend the length of the acceleration lane, thereby making it senior-proof. A different type of senior-proof acceleration lane is the introduction of a tool on the shoulder (or in-car, in that case the tool will be a senior-proof merging facility in the car) that shows the driver the required merging speed or the speed difference between the speed with which they are merging and the actual speed on the main carriageway at that time. This is the option that Ying (2010) proposes. The question is whether elderly road users are able to handle this extra information: he or she is deliberately opting for a slower merging speed. The question is also whether having elderly drivers increasing their speed will actually improve traffic safety. In theory, if the speed differences were clearly illustrated, this could prompt the elderly road user to reduce the difference in speed. Whether drivers can handle this information and consequently increase speed is unknown.

Options to enable elderly drivers to merge at higher speeds into the traffic on the main carriageway were examined in a survey. If the solution is sought in providing better information, the elderly drivers were subsequently asked how and what information should be offered in order to make it easy and safe to merge on the highway (Dijksterhuis et al., 2012). A highway sign and signal was developed as part of the research. Elderly road users stated⁸ that they clearly prefer the version below (see Figure 6). Practice will show whether this highway sign (or an alternative in-car solution) will actually help elderly drivers to merge.

![Fig. 6. The preference of elderly road users for a sign with speed indication on the acceleration lane.](image)

6. Time and space for and by elderly

The foregoing indicates in which direction additional, supporting facilities may be sought:

1. Supporting facilities are developed for and by the elderly target group;
2. Incorporate supporting facilities in the ‘time-travel’ search space as perceived by elderly drivers.

The two formulations above do not differ hugely from each other. With this direction in mind, it should be possible to design a senior-proof acceleration lane (SPAL).

The first option is to extend the existing acceleration lane. By increasing the length, the road user has extra road length and extra time to merge. A second option is to create a senior-proof acceleration lane within the dimensions of the existing acceleration lane (no physical road extension is created). As told in paragraph 5 Ying (2010) suggests displaying the difference in speed between merging drivers and other traffic on the main carriageway: providing this information will motivate the elderly road user to accelerate faster. This last measure does not immediately seem to fit in the general strategy (creating extra road length and/or extra time) which senior drivers generally apply when participating in traffic. However, this reasoning could be too simplistic. The

⁸Note that what people state or say that they prefer is not always equal to what is best to do in practice.
strategy of the senior driver always applies within a certain context. This means that the senior driver, if facilitated by the SPAL facility, shall create more time by accelerating sooner and creating more road length by accelerating sooner. The design of the SPAL facility is crucial. After all, if the facility will result in an increase in the ‘workload’, then this will not solve anything.

7. The importance of context

The analyses in the previous chapters and the discussion in chapter 6 illustrate which aspects can play a role in the senior proof design of the network. Although technology is constantly developing, it needs to be placed within the context of social developments. Furthermore, driver behaviour and perception also play an important role in the adoption of new technologies. With the introduction of new technologies, it is important to take the following aspects into consideration:

- The technological development and primarily the development of in-car facilities;
- The traffic psychological aspect.

The societal context also plays a role that should not be underestimated. The role of technology, its development, adoption and adaptation by people is largely driven by the societal context in which people live. This paper will not examine this role of societal context extensively, it is however recommended to develop further thought on this influence.

7.1. The technological development

Over the past decade, technological in-car innovations were applied on a large scale in vehicles. This resulted in a vehicle becoming increasingly intelligent. There are various reasons why these systems were developed:

- To make driving more comfortable in general;
- To assist in navigation and performing driving task (for example following a lead vehicle or lane keeping);
- Preventing accidents or minimising the impact of accidents.

The introduction of various driver assistance systems such as adaptive cruise control (ACC) and Lane Keeping Assist (LKA) has led to more and more parts of the driver’s task being taken over by the vehicle. This development is still continuing and has led to experiments with highly automated vehicles at different locations around the world. The question remains whether an automated vehicle will be able to take over all the driver’s tasks within the near future. In any case, because of advanced technology, vehicles are now more adept at detecting and neutralising the risk of accidents than human drivers.

The above-mentioned development is also relevant for elderly drivers, because in-car systems can compensate for the shortcomings of elderly drivers. However, this is only possible if these systems correctly fit in with the specific characteristics of elderly drivers. If this is not the case the situation could even worsen.

The question that emerges is whether these in-car developments are sufficient to the extent that the use and respectively further development of roadside systems become redundant. However, simply placing the initiative with in-car developments is too straightforward. For the time being, in-car facilities will not be able to assist with and/or take over all the driving tasks. It should also be taken into account that elderly people often feel a certain amount of resistance to using technological innovations. In addition to this, there is a clear desire for providing assistance with the driving task via in-car systems. Systems that are currently being developed like the Automated Highway Driving Assistant (Toyota) or the Merging Assistant (DITCM) can in nearby future create both extra time and space for elderly drivers.

7.2. ‘Human factors’ aspects

Alongside the development of infrastructure or technological solutions, there should also be a focus on the behavioural and psychological background of the elderly driver. This is because any effective solution will always take into account the ‘human factors’. These factors cannot be viewed separately from the technological solutions, because the solutions should lead to drivers adjusting their behaviour.

**Without being exhaustive: electronic stability control (ESC), anti-blocking system (ABS), adaptive cruise control ACC (including stop-and-go function), intelligent speed adaptation / speed alert, lane departure warning / lane keeping, forward collision warning, emergency braking systems, curve speed warning, blind spot warning, anti-roll systems, driver condition warning systems, etc.**
However, offering additional information may also cause additional workload for the senior driver. The driver is first required to perceive the information that is being provided. Next, the information must be processed, and the driver subsequently needs to understand what the information means and what is expected of him/her. If the driver understands it, he must also be willing and able to comply. And then carry it out. The willingness and ability to do something is also affected by other drivers. In some cases, a driver may want to respond but cannot because other drivers are driving much faster or slower. Simply offering the information does not always automatically result in the desired behaviour. Drivers may simply fail to perceive the information, lack time to process the information, fail to understand the information, or simply be unable or unwilling to perform this behaviour.

This information processing cycle also plays an important role within the context of the elderly driver, whereby processed information and the ability or desire to apply the information also depends on how the information is provided. The fact that this involves a migration /transition of ‘road side’ facilities to ‘in-car’ facilities plays an important role. The driver is offered more and more traffic management applications in his/her own cockpit. The driver gets more and more support from driver assistance systems like navigation systems and ACC (and in the future also cooperative adaptive cruise control C-ACC).

The application of this technology raises the following questions with regard to ‘the human factor’. The first question is how the elderly drivers will adjust their driving behaviour, for example, if a platoon of vehicles is connected to each other via vehicle-to-vehicle communication? This question applies to both elderly drivers that are part of a platoon, and elderly drivers that are driving individually and are confronted with a platoon. For example, elderly drivers may not have difficulty exiting a lane if platoons are driving faster than the senior driver and are not driving on the right lane. On the other hand, if this involves a platoon of trucks, the elderly driver may have more difficulty to exit the lane and could be tempted to reduce its speed to move behind the platoon and subsequently move to the right lane. How would elderly drivers respond to these kinds of traffic situations?

Next, the manoeuvre ‘merging on the motorway’ with additional information could mean an increase in the elderly drivers ‘workload’. Note that elderly people already consider merging to be a difficult manoeuvre. The addition of extra information could cause more uncertainty among elderly drivers and even lead to lower speeds. The question that needs to be answered is whether adding information about the desired merging speed leads to a higher speed of merging elderly drivers. An underlying question here is what would be the best moment to offer this information while merging? The question whether this information should be offered as an in-car application or along the side of the road, also needs to be answered. The benefit of an in-car solution seems to be that it would be possible to view the required merging speed of the merging manoeuvre at any time, and even link this to the speed on the main carriageway. If the information or advice does not lead to the desired behaviour it should be assessed whether this lies in the perception, information processing, understandability, or the ability or willingness to comply.

An additional question that should be asked here is - how exactly should this information be provided if it is provided along the side of the road? Should the information be repeated? Should the information be provided on the left or the right side of the road?

8. Conclusions, discussion and recommendations

Conclusions
This analysis examined a future scenario with a higher number of elderly drivers on the road. What are the potential traffic efficiency and safety effects and what action can the road administrator take? This scenario was approached from the point of view of a traffic engineering micro simulation, a design issue and a psychological level. We have chosen for this approach in the belief that future issues and questions concerning the infrastructure and people will call for an integrated approach.

The first thing that was determined is that elderly drivers do benefit from facilities that facilitate the merging manoeuvre, at least if well designed and with the abilities and limitations of the elderly driver in mind. Paragraph 7.2 illustrates that there are still many unanswered questions regarding this ‘human factor’. Further research is needed with regard to behaviour and human factors to make the infrastructure, and specifically its use for the merging manoeuvre, ‘senior proof’.

Discussion
Elderly drivers have been known to solve problems that they encounter while driving, by creating more space and time, often realised by reducing speed. However, depending on the traffic situation, applying this strategy is not always possible. It is true that elderly drivers are experienced and are often creative in finding more time and
space. Senior road users will create extra time by keeping to lower average speeds, mainly at locations where there is a lot of interaction between different road users, or by waiting longer at intersections in order to use a larger gap between vehicles. It would be interesting to examine how senior road users could be assisted at these locations.

If the possible solution of extra time and space concerns the infrastructure, which is often the case, then the road administrator will need to play a crucial role in assisting the search strategy of the elderly driver. As mentioned in the previous paragraphs, this should be carried out in co-operation with other institutions like universities and knowledge institutes (also addressing the societal context).

**Recommendations**

The results of the simulation runs show differences in the capacity and possibly also higher safety risks of highways as a result of an increase in the number of senior drivers that will be using the highway in the future. The differences are not huge, but they represent a change that needs to be taken into account. What does this mean for the infrastructure?

Besides possibilities e.g. additional length for merging traffic, additional road-side information or in-vehicle equipment, it is also important to keep high standards for the normal road layout. Even though it is important for all road users, for elderly drivers it is even more important that the road design is as predictable as possible (and that for instance road marking are clear and well-maintained††).

Furthermore, road authorities play an important role in enabling senior road users to find the required extra time and space. The approach could be based on existing principles, but also on new concepts that will be developed. The design principle for these new concepts should be ‘design for all’: what is effective for elderly drivers is in almost all cases also effective for all drivers.

Human factors are the boundary conditions for these new concepts. To assess the concepts additional studies are required on the effects of these concepts on elderly driving behaviour and the interaction with the other traffic users under varying traffic situations.

**References**


Friso, K. en J. de Kruijf (2010). *Vergrijzing en mobiliteit. Hoe gedraagt de toekomstige oudere zich in het verkeer? Onderzoek naar een bredere toepassing van verkeersmodellen door rekening te houden met...

†† Also see Davidse (2002, 2007) and Davidse et al. (2009).


