CONSIDERING THE REQUIREMENTS OF ELDERLY ROAD USERS IN TRAFFIC SIGNAL CONTROL

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Abstract

The share of elderly road users in total traffic is increasing in Germany as well as in most other OECD countries. To ensure mobility and road safety for this fast growing group, special requirements regarding the essential characteristics of elderly road users have to be considered in transport system design. Besides basic requirements in transport planning, traffic engineering can help significantly to improve mobility and road safety for the elderly.

Accordingly, this paper outlines the consideration of elderly road users' requirements in traffic signal control by analysing standards from Germany, United States, United Kingdom and other selected countries as well as examples from practice. In detail, the consideration of the elderly is discussed for the topics signal program design, intersection layout, control strategies, and technical design of signal lights. The paper closes with conclusions on how well the requirements of elderly road users are considered in traffic signal standards already and highlights the need to apply such regulations in practice, despite omnipresent goal conflicts and financial constraints.

Keywords: Traffic signal control, elderly people, mobility, road safety

1 Introduction

The group of elderly road users, here road users older than 65 years, has an increasing share in total traffic in most OECD countries. This is also confirmed by several forecasts which indicate an increase of the population over 65 years by 25 % until 2030 and of the population over 80 years by more than 12 % until 2050 (cf. Schlag, 2013; FHWA, 2014a; Weller et al., 2014).

For example, the demographic change between 2013 and 2080 shows that population in Europe will continue ageing (cf. Figure 1). While the share of the working population will drop steadily, the population over 65 years will account for 28.7 % by 2080, compared to 18.2 % in 2013 (Eurostat, 2014). According to these estimations, FHWA (2014a) suggests that the "design driver" and the "design pedestrian" of the 21st century for many aspects of road planning and design will likely be over 65 years.

To ensure mobility and road safety of elderly people, the special requirements of this fast growing population group need to be considered in transport system design. This concerns the design of infrastructure as well as operational measures. In particular, traffic engineering - comprising traffic signals, markings, signing, guidance and information systems, and other traffic management systems - is important for a safe and barrier-free transport.

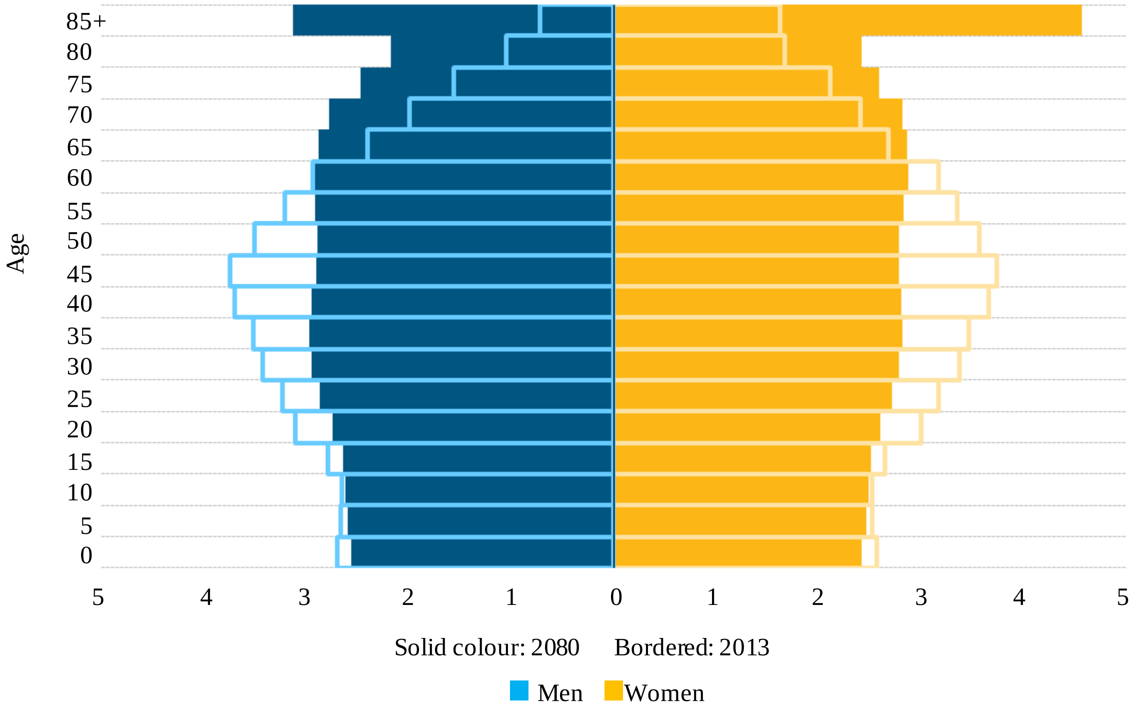

Figure 1 – Changes of population pyramids for the European Union between 2013 and 2080 (Source: Eurostat, 2014)

Compared to other age groups essential characteristics of the group of elderly road users are as follows:

- Poor eye-sight and hearing,
- Limitations of movements (e.g. mobility impairments, including the use of a wheelchair and walking frame),
- Less ability to pay attention and to respond,
- More frequent excessive demand in new and complex situations,
- Reduced fitness and faster physical fatigue.

(cf. Limbourg, 1999; Kay et al., 2008; Schlag, 2008; Boenke, 2011; Boenke & Gerlach, 2011; Scott et al., 2012; Schlag, 2013; Staplin, 2014)

While more and more elderly people are actively taking part in road traffic, they are - compared to younger people - exposed to higher accident risk. Irrespective of transport mode, the risk of being killed in an accident increases from the age of 65 years (cf. Gerlach et al., 2007; Schlag, 2013; Ewert & Uhr, 2014).

The major reasons for accidents involving elderly people can be clearly identified. E.g., detailed analyses can be found in Abou-Raya & Abd ElMeguid (2009), Boenke & Gerlach (2011), or Weller et al. (2014). The majority of accidents involving the elderly are related to car use (cf. Rakotonirainy et al., 2012; Ewert & Uhr, 2014; Bakaba & Ortlepp, 2015).

For fatalities from car accidents typical conflict situations can be identified. For instance, Boenke & Gerlach (2011) state that accidents often occur while turning left at traffic signals and while turning or crossing the intersection without traffic signals. Another frequent reason for traffic accidents is ignoring traffic signs or road hazards (cf. Abou-Raya & Abd ElMeguid, 2009; Rakotonirainy et al., 2012).

A high fatality rate in traffic accidents can also be identified for elderly pedestrians (cf. Boenke & Gerlach, 2011). Because elderly people tend to avoid detours more than others, accidents of elderly pedestrians often occur aside safe crossing facilities. Based on analyses of elderly pedestrian accidents, Abou-Raya & Abd ElMeguid (2009) reveal that most of the accidents occur due to falls, for example, when crossing the street. Furthermore, elderly pedestrians and cyclists often crash at intersections with priority signs (cf. Topp, 2014). In many cases, a non-situation-specific infrastructure design and incorrect behaviour of elderly cyclists are the main accident cause.

To reduce the number of accidents, the specific requirements of elderly road users must be considered in any traffic engineering task. Of course, experiences from accident statistics must be utilised. It is beyond all question that improvements should be found as soon as an conspicuous accident involvement of the elderly is detected. Other reasons for a strengthened consideration of elderly people´s requirements may be own observations of the traffic engineer or information on high volumes of elderly people at a traffic facility (e.g. near a retirement home).

Given the great diversity of relevant traffic signal control aspects, for the content of this paper four exemplary topics have been selected. The main objective of this paper is the discussion of the consideration of elderlys' requirements for each topic based on regulations from Germany and selected other countries. So, the consideration of the elderly is discussed for signal program design, intersection layout, control strategies and technical design of signal lights. The paper closes with short conclusions on how requirements of elderly people are considered in the different countries. Finally, recommendations regarding further improvements in respect of elderlys' requirements in practice are provided.

2 Basic Requirements of Elderly Road Users

Based on changes in the capabilities of ageing people and on experiences in accident occurrence, general aspects which are relevant for traffic engineering and corresponding basic requirements for the design of transport systems can be derived. Essentially, these are:

- Reduction of complexity of traffic situations.
- Improvement of the perception of traffic regulations and traffic systems.
- Design of safe crossing facilities; avoiding detours for (elderly) pedestrians and cyclists.

For decision makers and traffic engineers, it is necessary to consider manifold requirements in different goal fields (safety, mobility, environment, economy) for different transport modes, user groups and stakeholders (road users, operators, residents). Despite all efforts to address the requirements of elderly road users in traffic engineering, goal conflicts and synergies are omnipresent. However, goal conflicts require a careful and transparent consideration for those who are affected. The implementation of bundled measures often helps to achieve good compromises. Synergies should be achieved, and it should be aware that many measures implemented to improve the situation for elderly people do also bear benefits for other road users.

3 Consideration in Traffic Signal Standards

For the design of traffic signals, the German Guidelines for Traffic Signals "RiLSA" (FGSV, 2010a) contain comprehensive instructions and recommendations. It can be stated that the requirements of elderly people will be sufficiently considered if traffic engineers follow the instructions of this standard during the implementation phase. However, in practice, many of the numerous goal conflicts are not solved in favour of the elderly. Therefore, the major issue for the case of Germany is to create awareness of the requirements of the elderly when designing traffic signals and to consider their needs appropriately in weighing and balancing of goal conflicts. In this regard, the following sections elaborate some particular aspects.

In the U.S., the "Handbook for Designing Roadways for the Aging Population" (FHWA, 2014a) was published which includes proven treatments and recommendations to address the requirements of ageing road users in highway design, operational and traffic engineering features such as traffic signals. Furthermore, the "Traffic Signal Timing Manual" (FHWA, 2008) and the "Highway Capacity Manual" (TRB, 2010) provide recommendations regarding specific aspects, e.g. walking speed, which concern the requirements of elderly people.

In the United Kingdom (U.K.), guidelines for street design regarding the requirements of elderly people were developed in the research project I'DGO (2012) which include, inter alia, the signalisation of pedestrian crossings. But also in other countries such as Japan (cf. Okamura, 2014) and Switzerland (cf. Ewert & Uhr, 2014) requirements of elderly people in traffic signal control are a specific aspect of research.

4 Signal Program Design

4.1 General Requirements

In order to consider the requirements of elderly road users, complex traffic situations have to be avoided (cf. Topp, 2014; Welch, 2014). For example, elderly drivers often struggle with left-turn movements having to consider the priority of several traffic streams. Nearly the same problems are existing for elderly pedestrians at crossings where they have to observe different signalling states for several carriageways for cars and additional bus lanes or tram lines.

4.2 Phase Organisation and Phase Sequence

Regarding phase organisation and phase sequence, engineers should seek for completely protected movements of traffic streams. Usually this will lead to a substantial benefit in traffic safety. Calculations of capacity losses resulting from additional phase switches and intergreen times should consider the effective green time. While in the U.S., the effective green time is included in TRB (2010), this aspect is not considered sufficiently in the German standards so far (cf. Boltze & Wolfermann, 2011). As far as capacity reasons contradict separate, protected movements especially for left-turners, it should be considered that these problems usually occur in a few peak hours, only. Usually a variable movement protection (during the day partly protected, partly non-protected) is not applied because other signalling conditions must be considered (e.g. in Germany, separate signal heads with direction arrows always require a protected movement) and problems with certain regulations may arise due to familiarisation (drivers may expect a protected movement at all times). For safety reasons, a leading green should be used very carefully, and specifically with respect to elderly drivers the danger of misunderstanding must be critically considered. In contrast, considering the requirements of elderly people, FHWA (2014a) recommends that a leading protected left-turn phase should be implemented wherever protected left-turn signal operation is applied.

4.3 Right-turn on Red

The right-turn movement on red (in Germany allowed by a static green arrow sign, cf. Figure 2) is one of the complex traffic situations, which may overburden elderly drivers and pedestrians. Therefore, the German green arrow should not be used at intersections, which are crossed by blind people or the visually and physically impaired (FGSV, 2010a). Detailed instructions on the disadvantages of the green arrow sign for elderly road users can be found in Boenke et al. (2010). According to the authors, significant disadvantages occur for partially sighted people who cannot clearly differentiate between flowing and stopping traffic in ambient noise. In addition, the authors point out that especially for elderly drivers the right-turn on red can cause problematic situations because this regulation is ambiguous and the elderly may not expect a traffic flow from a direction where traffic is stopped with a red signal. In the U.S., the right-turn on red is common. But in order to consider the requirements of elderly drivers and pedestrians, such regulation should not be implemented (FHWA, 2001).

Figure 2 – Static green arrow sign in Germany (Source: TU Darmstadt, Chair of Transport Planning and Traffic Engineering)

4.4 Signalised Pedestrian Crossings

Increasingly signalised pedestrian crossings are required to prevent elderly road users from danger while crossing the road (cf. Figure 3). For this purpose, FGSV (2010a) provides comprehensive recommendations which highlight advantages and disadvantages of various design possibilities for the group of the elderly. E.g., pedestrian traffic signals should usually be operated as a request signal to minimise waiting times for pedestrians. In this case, by showing additional information (e.g. "green signal is coming") pedestrians know that their request has been registered. Because of pedestrians which are used to car traffic and its signals, car traffic streams of both directions should receive red light at the same time. In case of green waves, green times which are not required for car movements, should be used for the extension of pedestrian green times.

Figure 3 – Pedestrians and cyclists at traffic signal (Source: TU Darmstadt, Chair of Transport Planning and Traffic Engineering)

FGSV (2010a) also contains detailed information about signalling crossing facilities for railway tracks. E.g., for blind and partially sighted people the track area should be signalised to achieve a safe operation of public transport vehicles, and the green times should be displayed acoustically and additionally tactile. Furthermore, the installation of pedestrian traffic signals is important for elderly pedestrians because at alternatively established types of crossings (e.g. "zebra crossing" in Germany) more safety problems may exist. These types of crossings without traffic signals are formally giving the right-of-way to pedestrians. However, in practice a lack of monitoring and enforcement often leads to low acceptance of such a rule by car drivers, creating uncertainties for pedestrians.

In the U.K., four common traffic signals for pedestrians named Pelican, Puffin, Toucan and Pegasus are implemented (cf. AASHTO, 2010; I'DGO, 2012). At the Pelican crossing a flashing green indicates that pedestrians should not start to cross any more. Puffin crossings are equipped infrared detectors and enable people to cross in their own time which is beneficial for elderly pedestrians. Furthermore, a control panel is installed at the nearside of the crossing which provides a better visibility of signals especially for visually impaired people. Toucan and Pegasus crossings have the same functions as Pelican and Puffin. Toucan crossings are implemented for pedestrians and cyclists while Pegasus crossings are used where pedestrians and equestrians share a crossing facility. The diversity of these crossing types leads to a lack of understanding regarding priority especially for elderly pedestrians and drivers. Therefore, I'DGO (2012) recommends that the diversity of pedestrian crossings should be reduced in favour of simplicity for elderly people.

In the U.S., pedestrian crossings are signalised in the three intervals 'walk', 'flashing don't walk' and 'don't walk'. According to FHWA (2008), the interval 'flashing don't walk' is "an indication warning pedestrians that the 'walk' indication has ended and the 'don't walk' indication will begin at the end of the pedestrian clearance interval". This interval is often supported by displaying the remaining time for pedestrians to pass the crossing facility (cf. Figure 4). For elderly people, FHWA (2014a) recommends to install countdown pedestrian signals at all signalised intersections because countdown signals decrease pedestrian crashes while reducing the percentage of pedestrians still in the crosswalk when the signal turns red. Besides the U.S., countdown pedestrian signals are installed in Japan and Singapore, inter alia.

Figure 4 – Rules for using traffic lights for pedestrians and displaying remaining time for pedestrians in North America (Source: TU Darmstadt, Chair of Transport Planning and Traffic Engineering)

Also in Germany, displaying the clearance time for pedestrians should be considered in the future. This could clarify the traffic situation particularly for the elderly people, which are walking slower and may have to utilise the whole clearance time. For the feasibility of different approaches (amber signal, flashing green, flashing red, displaying the remaining time until the end of clearance time for pedestrians) more research and a comparative analysis of international experience with different solutions is required.

4.5 Transition Times

In Germany, the existing regulations for transition times AMBER and RED/AMBER have been proven for car traffic and bicycle traffic. For the elderly adjustment is not required. It can be assumed that age-related changes in reaction times can be easily compensated within the current durations of signalled transition times.

In the U.S., the Netherlands, Japan and Australia, the clearance distance is considered in the determination of red clearance time, so-called all-red time. The all-red time gives additional time to vehicles which are already in the intersection to safely pass the intersection before conflicting signal groups are triggered (Mishra & Zhu, 2013). In the determination definitions vary in details (e.g. FHWA, 2008; Tang & Nakamura, 2009; TRB, 2010; NCHRP, 2012). To adapt perception/reaction time to ageing people, an all-red time should be consistently implemented. Furthermore, based on the study of FHWA (1995), which compared decision/response times and deceleration characteristics between elderly and younger drivers at amber time beginning, the authors state that there is no need for changing to accommodate ageing drivers. This is also recommended by FHWA (2014a).

4.6 Intergreen Times and Pedestrian Clearance Speed

Intergreen times are defined as the time between the end of green for one traffic stream and the beginning of green for another (conflicting) traffic stream. Intergreen times have significant impact on safety and capacity of intersections with traffic signals. Long clearance times of elderly people are critical due to lower walking speed. For this purpose, the German traffic signal expert committees had comprehensive discussions and considerations with associations representing people with disabilities during the compilation of the German traffic signal standard (FGSV, 2010a). Setting lower walking speed for clearance would extend the intergreen time and reduce the capacity of signalised intersections significantly. The practical implications have been regarded as critical, and after careful consideration the revised version of FGSV (2010a) defines the pedestrian clearance speed at 1.2 m/s, with the possibility of variations in the range of 1.0 to 1.5 m/s. If crossings are specifically installed to protect handicapped people, the lower value should be used. The guidelines for barrier-free traffic facilities (FGSV, 2011) also recommend a clearance speed of 1.0 m/s to be used for calculation.

In the U.S., the Highway Capacity Manual (TRB, 2010) states that walking speed depends on the characteristics of the walking population. Therefore, different values should be used according to the proportion of children and elderly pedestrians. If the proportion of elderly pedestrians is lower than 20 %, the value 3.5 ft/s (1.07 m/s) should be used. But if the proportion of elderly pedestrians is higher than 20 %, the decreased value of 3.0 ft/s (0.91 m/s) can be used. FHWA (2014a) also recommends the use of a decreased value to accommodate of ageing people. In contrast, in the U.K. and Switzerland a walking speed of 1.2 m/s is considered at all pedestrian crossings (cf. Alrutz et al., 2012; I'DGO, 2012).

A very important aspect for choosing the pedestrian clearance speed is that particularly slow-moving people should be aware of their situation, and they should enter the crossing at the beginning of green time (and not at the end). According to German regulations (FGSV, 2010a), the minimum green time should be calculated for passing half of the pedestrian crossing, and the clearance time for passing the entire crossing. Therefore, even with a calculation of green time and clearance time based on 1.2 m/s, pedestrians starting at the onset of green can pass the crossing completely until the end of clearance time even at speed of 0.8 m/s. If additional acoustic devices for blind and partially sighted people exist, according to FGSV (2010a) the minimum green time must be designed for passing the entire crossing length. In such a condition while using the lower value of 1.0 m/s, pedestrians can even clear in time with a speed of 0.5 m/s given they start at the beginning of green time.

In this context, in Germany it was already called for special buttons or touch sensors to request a longer pedestrian clearance time and green time. Given the generally sufficient regulations of FGSV (2010a), the effects on the capacity for other road users, the technical complexity and the risk of misuse, a wider use of such buttons or sensors seems not to be appropriate for the case of Germany.

However, Singapore started the program “Green Man Plus” in 2009 which includes a solution for misuse. Elderly people and people with disabilities can influence the pedestrian green time by tapping their senior citizen concession or so-called Green Man + card on the card reader on the traffic light pole (cf. Figure 5). Depending on the size of crossing, elderly pedestrians can be provided with an additional green time up to 13 seconds. The buttons are accepted by elderly people, and so it is planned to expand this technique to further pedestrian crossings. (LTA, 2013)

Figure 5 – Requesting longer green time for elderly people with a Green Man+ card in Singapore (Source: Spiegel.online, 2014)

This example of intergreen times and pedestrian clearance speed shows that compromises are very necessary to consider the requirements of elderly road users in practice.

The descriptions for the longer clearance times of pedestrians can be applied analogously to elderly cyclists. This should also be taken into account when selecting the type of signalisation for cyclists (separate, together with motorized traffic, together with pedestrians).

4.7 Cycle Time and Green Times

For cycle time and green times FGSV (2010a) provides comprehensive advice which allows to consider the requirements of elderly road users adequately. Specifically for elderly pedestrians, short waiting times and short cycle times are aspired. However, this is at odds with demand for protected left-turn movements and sufficiently long green times for (elderly) pedestrians. A fair balance is necessary for each individual case.

The German Guidelines for Traffic Signals (FGSV, 2010a) state that, in general, minimum green times are not allowed to fall below 5 seconds. The Traffic Signal Timing Manual (FHWA, 2008) recommends minimum walk duration of 7 seconds. However, in school zones and areas with high proportion of elderly pedestrians longer walk durations should be considered. As an additional rule in Germany, pedestrians should be able to cross at least half of the road width during green. This value increases to the complete carriageway at crossings providing additional acoustic equipment for blind and partially sighted people. If in one phase two successive crossings should be passed, the green time should be long enough to cross the longer crossing, the central island/separating strip, plus half of the second crossing.

Altogether, many signalisation standards already explicitly claim for a design of the signal program which should be as much pedestrian-friendly as possible. Basically, when applied in a consistent way, this can fulfil the requirements of elderly road users quite well already.

5 Intersection Layout

5.1 General Requirements

While designing intersections with traffic signals numerous aspects have to be considered to cope with the interests of elderly road users and the above-mentioned basic requirements. This includes, inter alia,

- simple and clear intersection design,
- as orthogonal as possible intersection angle,
- adequate sight distance,
- sufficient broad lanes,
- small turning radius (in order to keep intersections compact and speeds low),
- sufficient long integration routes with lane drop offs on intersection exits and
- sufficient broad separating strips and central islands.

(cf. AASHTO, 2010; I'DGO, 2012; FHWA, 2014a; Topp, 2014; Weller et al., 2014)

Basically, the regulations for these design elements appear to be sufficient for elderly road users. However, in practice lower values are often accepted to cope with specific restrictions or other objectives. In individual cases, a compromise should be based on a careful weighing process.

5.2 Routing of Pedestrians and Cyclists

In intersection design, the routing of pedestrians and cyclists needs special attention. For instance, compared to signalised intersections roundabouts are detrimental for elderly pedestrians. Although roundabouts reduce the number of conflict points (Weller et al., 2014), longer walking paths and the absence of aids (e.g. acoustic signal heads) are disadvantageous.

In addition, for elderly road users the routing should be easy to understand. As shown in Figure 6, removing crossings or eliminating crossing facilities in individual approaches bares disadvantages and leads to detours which should be avoided.

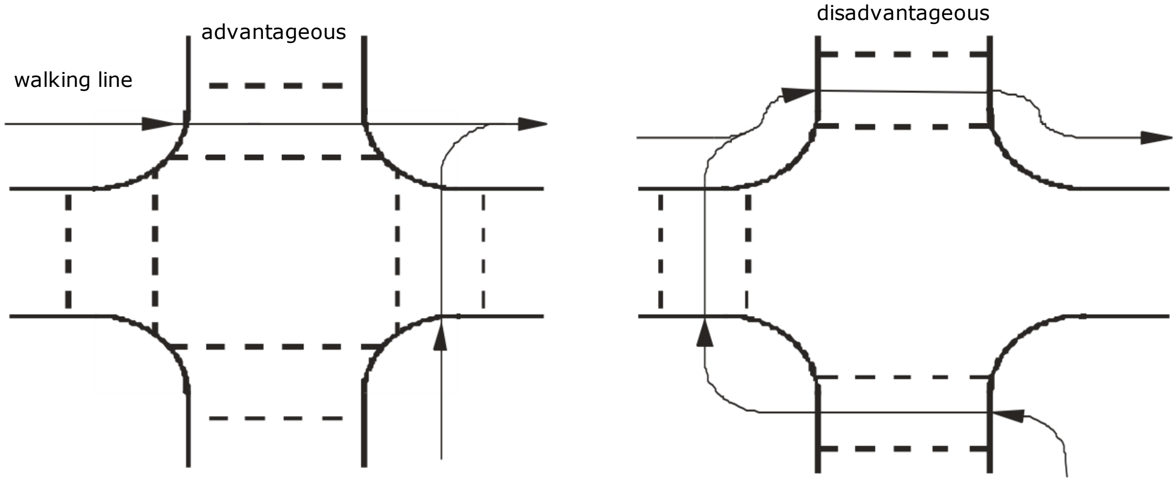

Figure 6 – Advantageous and disadvantageous location of crossings at signalised intersections (Source: FGSV, 2002)

For elderly cyclists, to implement an indirect left-turning movement with corresponding queuing spaces it is an alternative to direct routing at complex intersections (cf. Figure 7; Boenke et al., 2010). A clear organisation and understanding of intersections is also important for elderly car drivers to avoid conflicts with pedestrians and cyclists (cf. Topp, 2014).

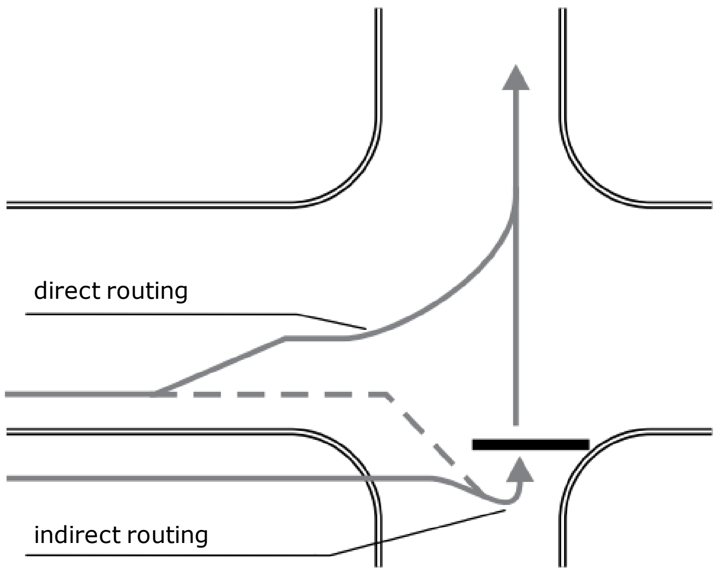

Figure 7 – Direct and indirect routing of left-turning bicycles at intersections (Source: FGSV, 2010b)

5.3 Triangular Islands

Triangular islands seem rather detrimental for elderly people because it affects the clearness of intersection, and leads to longer paths for pedestrians. The free movement of right-turners at high speeds behind a triangular island is particularly critical because this may lead to conflicts with unprotected crossing pedestrians. If triangular islands are implemented, a clearly understandable and well-protected routing of pedestrians and cyclists must be achieved. At triangular islands a protected crossing of the right-turning lane is preferable. FGSV (2010a) provides more detailed information.

In the U.S., for pedestrian crossings right-turn channelisation should be considered during design. If the right-turn lane is channelised, FHWA (2014a) recommends that the crossing should be located approximately one car-length from the stop line for the intersection (cf. Figure 8).

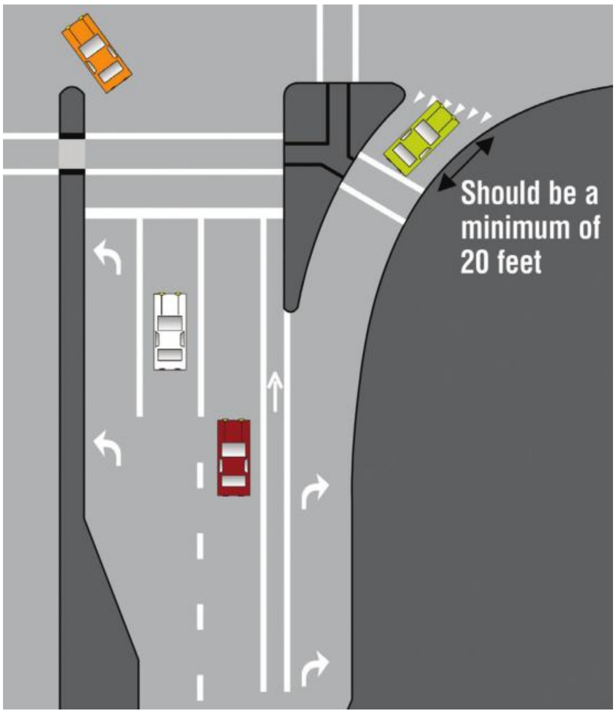

Figure 8 – Pedestrian crossing at channelised right-turn lane (Source: FHWA, 2014a)

Furthermore, the turning radius has to be considered. A tighter turning radius can reduce turning speed, decrease pedestrian crossing distances, and optimise the right-turning car drivers' line of sight (FHWA, 2014b).

6 Control Strategies

6.1 General Requirements

Regarding FGSV (2010a), control strategies can be distinguished in a macroscopic and a microscopic control level. The macroscopic control level considers long-term changes of traffic volumes in the road network or at single intersections, and it activates the specific signal programs. The signal programs are selected time-dependent or traffic-actuated and are activated for a period of at least several cycles. In contrast, the microscopic control level considers short-term changes (e.g. every second) in traffic condition at single intersections.

In practice, the applied control strategies at the macroscopic and microscopic control level are not directly perceived by road users. Besides the information of FGSV (2010a) only a few specific aspects regarding elderly road users have be considered.

It should be taken into account that elderly road users get used to certain processes more than others, their behaviour is especially controlled by expectations. Surprising changes in the signal program sequence can cause misunderstanding and malfunction. Therefore, time-dependent activated signal programs should be designed to not be very different from each other.

6.2 Traffic-actuated Control Strategies

In order to reduce waiting times especially for pedestrians and cyclists traffic-actuated control strategies are possible, where the detection of pedestrians and cyclists takes places or they are able to request a green signal. Push buttons or touch sensors for requesting the green signal by pedestrians and cyclists, which are signalised together, should be clearly visible, discoverable and accessible and confirm that the request is well perceptible. A common use and further development of detection technique for pedestrians and cyclists, which require no more action by the road users, should be supported.

6.3 Overnight Shutdown of Traffic Signals

Because elderly road users need the protection of traffic signals, an overnight shutdown of traffic signal operation should be avoided in their interest. Specifically, traffic signals should not be switched off when they are equipped with additional devices for the blind and partially sighted people (cf. Boenke et al., 2010). Also, FHWA (2014a) recommends traffic signal intensity should not be reduced during nighttime operations. In general, the shutdown of traffic signal operation during nighttime may lead to some savings of waiting time and energy. However, it must be considered as very critical regarding traffic safety, not only for elderly road users. It is not recommended.

7 Technical Design of Signal Lights

7.1 Recognisability of Signals

For the technical design of signal lights comprehensive regulations are already provided, which are mentioned in detail e.g. in FGSV (2010a) and FHWA (2009).

In terms of elderly road users the recognisability of signals should be considered. In Germany, signal heads with optical units of 200 mm in diameter are widely used. FGSV (2010a) identifies situations in which the use of signal heads with a larger diameter of the optical unit (300 mm) is recommended. Taking into account the requirements of elderly road users in such decisions, larger signal heads should be selected in the future. For longer pedestrian crossings it should be considered that partially sighted pedestrians can still see the signal heads located on the other side of the lane. In case of doubt, larger or brighter signal heads should be considered or additional devices for the blind and partially sighted should be used.

Scott et al. (2012) evaluated the visibility of pedestrian signals by people with varying visual acuities under different conditions of symbol size, crossing length and type of background behind the pedestrian signal. As a result, they state that a symbol size of 9- and 12-inch (228.6 mm and 304.8 mm) leads to a better recognisability for elderly people than a symbol size of 6-inch (152.4 mm). To improve the visibility of signal heads for elderly people, the installation of 12-inch signal heads and providing yellow retroreflective borders on backplates for traffic lights are recommended (cf. FHWA, 2014a; FHWA, 2014b; Welch, 2014; Weller et al., 2014).

7.2 Additional Signals

Due to the larger number of elderly people, the number of blind or partially sighted people will also increase. Therefore, acoustic and tactile signal heads will become more and more important and widespread. For Germany, FGSV (2010a) and DIN 32981 contain detailed specifications.

In order to increase the attention of elderly road users in difficult local situations, auxiliary signal heads should be used to protect against dangers. The principle of economic use persists in order not to wear down the warning effect of yellow flashing light due to frequent application. (FGSV, 2010a) Hamaoka et al. (2012) have investigated the effects of auxiliary signal heads on crossing behaviour of pedestrians. Pedestrians were informed about approaching right-turning vehicles by using an audible alarm. Field experiments presented that elderly people were highly influenced by the alarm system. Furthermore, the comparison with/without alarm showed that the alarm leads to a decrease of elderlys' head/neck flexibility.

To convey the current signalling status for elderly road users clearly, a sufficient number and arrangement of the signal heads should be implemented. Regarding this aspect, FHWA (2009), FGSV (2010a) and FHWA (2014a) provide detailed information. They also cope with the requirements of elderly road users if arrangement of signal heads is planned carefully and implemented consistently.

8 Conclusion and Outlook

In the OECD countries, the share of the group of elderly road users in total traffic increases significantly. To ensure mobility and road safety of this fast growing population group, special requirements for traffic systems regarding the essential characteristics of elderly road users, e.g. bad sight and less attention performance, need to be considered. In traffic engineering, on the one hand, the structural design of infrastructure and, on the other hand, operational measures are concerned.

Besides basic requirements in transport planning such as reducing the complexity of traffic situations and designing safe crossing facilities, traffic signal control can significantly help to ensure mobility and road safety for elderly people. Thus, the requirements of elderly people have to be considered in planning, implementation and operation of traffic signals which includes the signal program design, the intersection layout, the control strategies, and the technical design of signal lights.

An analysis of traffic signal standards from Germany, U.S., U.K., and selected other countries as well as examples from practice has proven that in the mentioned aspects of traffic signal control the specific requirements of elderly road users are already largely considered. There are several positive examples, among others the German Guidelines for Traffic Signal Control (FGSV, 2010a) and the U.S. "Handbook for designing roadways for the ageing population" (FHWA, 2014a), which already reflect the needs of elderly people to a major extent. The compilation of different regulations for the elderly road users in these standards provides comprehensive information also for those countries which plan to develop their own standards further. The number of conferences and research projects on this topic, such as "The design of streets with older people in mind" in the U.K. (cf. I'DGO, 2012), indicates that meanwhile the elderlys' requirements in traffic and transport are a special and important aspect of research all over the world.

However, having standards with full consideration of the needs of elderly road users is one thing, getting these favourable regulations applied in practice another. Even in countries with highly developed standards, we can observe quite often that the traffic facilities are not designed and operated according to the needs of elderly road users. On the one hand, this is due to lack of financial resources that prevent high quality design and appropriate maintenance. On the other hand, there are the omnipresent conflicts with other objectives and the requirements of other road users. Thus, in the weighting process requirements of elderly road users are often not considered sufficiently so far.

Accordingly, to achieve practical improvements for elderly people it is not only necessary to consider their needs in the relevant standards. There is also a need for an appropriate consideration of their requirements in the planning and decision-making processes, including careful and transparent decision-making in case of goal conflicts. Politicians are requested to provide adequate financial resources to ensure the quality of the traffic systems for the elderly. Finally, all these considerations of requirements of elderly road users must not be a concern just once, but this must to be integrated into a continuous transport planning process and in a systematic quality management. The efforts in favour of elderly road users will certainly pay off, because usually a benefit for all road users can be achieved from these measures.

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