German Insurance Association No. 40

Compact accident research

Safe intersections for vulnerable road users

Unfallforschung der Versicherer
GDV

Impressum

German Insurance Association
German Insureres Accident Research

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Published: 04/2015

Preliminary remarks

„Vulnerable road users“ require special protection in traffic. However, there is no need to draft any new age- or group-specific design regulations or guidelines. These are the conclusions drawn from a study commissioned by the UDV (German Insurers Accident Research) which focused in particular on the frequency and nature of accidents at intersections and junctions in built-up areas as well as on the correlations with the existing infrastructure.

The design of intersections which were characterized by high accident levels often did not comply with the planning recommendations set out in modern guidelines and regulations and therefore did not correspond to the current state of the art or meet road safety requirements. Many of the identified deficiencies, which in some cases were directly related to the frequency and nature of the recorded accidents, would not occur at intersections designed in accordance with current guidelines and regulations.

Existing current guidelines and regulations are capable of providing a high level of protection for „vulnerable road users“ provided that they are applied appropriately and consistently. However, more exacting regulations concerning the use of signal control for traffic turning left (across the oncoming traffic) would be particularly beneficial for older drivers and would furthermore generally help improve road safety at intersections. The same is true when it comes to ensuring adequate sight areas which enhance safety for all road users and for children in particular.

Content

1 Introduction

Children, older people and people with particular restrictions to mobility or mobility-related disabilities are frequently disadvantaged in traffic due to their physical and cognitive limitations. Such individuals number among the so-called "vulnerable road users". This situation is further exacerbated by the fact that these groups of persons are subject to particularly severe, and indeed even fatal (older road users), injuries when using the road on foot or as cyclists. In the case of older people, the increased risk of fatal injury when exposed to accidents of the same level of severity as other road users is a further negative factor influencing accident outcomes. In this context, the risks at intersections are particularly high. More than half of the accidents that occur in built-up areas take place at intersections [1].

In order to provide an efficient approach to increasing road safety for "vulnerable road users", the UDV conducted the research project "Safe intersections for vulnerable road users" [2]. Its results include recommendations for intersection design as well as recommendations for action relating to the drafting and application of guidelines and regulations.

Special attention was paid to the issues of pedestrian and cyclist road use by children and young people (14 years or less) and older road users (65 years or more). In addition, older people were also primarily considered in their role as drivers. The use of public transport (buses and trains) and road use as passenger were not included in the scope of the current study. The results presented for the group of individuals with particular restrictions to mobility or mobility-related disabilities were also based on requirements communicated in response to queries to the relevant umbrella organizations as well as on third-party research results.

2 Methodology of the investigation

To establish the basis for the research at the start of the study, the project concentrated primarily on the requirements of children, older people and people with particular restrictions to mobility or mobility-related disabilities, whose traffic-related needs

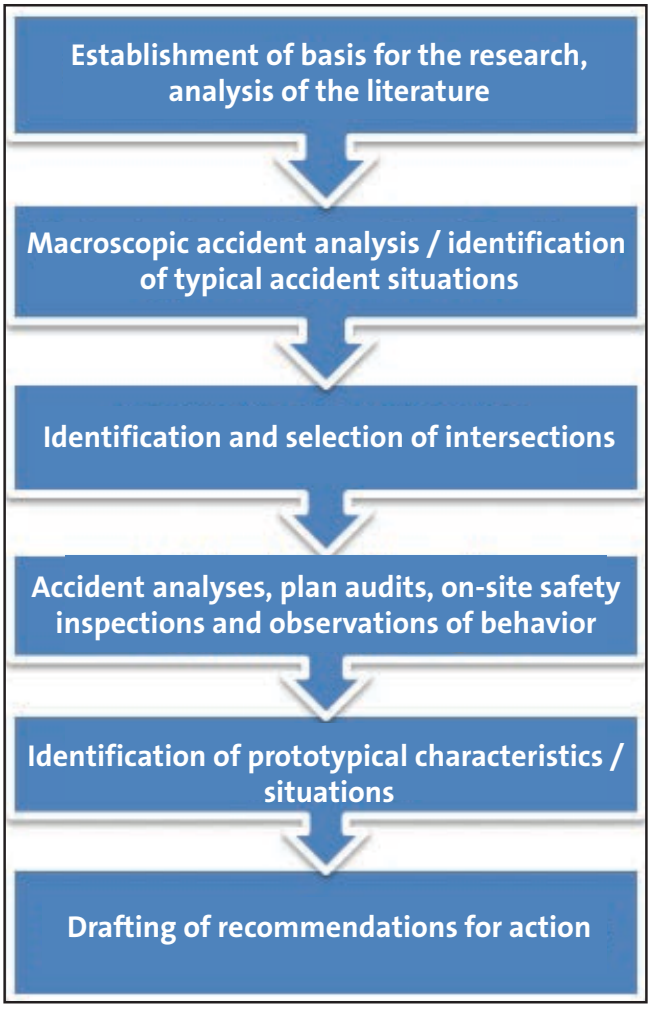

Figure 1:
Structure of the study (modules)

depend primarily on their physiological and psychological capabilities.

In addition, computer-archived accident data covering several years from five German federal states was subjected to a macroscopic analysis. This made it possible to identify frequent (typical) accident situations at intersections. Another focal point consisted of accidents to children and older people. The frequency and nature of accidents to people with impaired mobility were also examined on the basis of case studies.

Based primarily on typical accident situations involving children and older people, a number of intersections were selected for further observation. Initially, 291 intersections were identified at which the typical accidents to children and older people occurred (relatively) frequently. This initial selection was then narrowed down on the basis of criteria such as type of intersection, traffic control and the number of accidents involving children and/or older people as a proportion of the total number of accidents, first to 50 intersections in built-up areas and then subsequently to a total of 15 intersections for detailed study.

The detailed studies included:
- Accident analyses
- Audits of the planning documents
- On-site safety inspections, and
- Observation of behavior under real traffic conditions.

In addition to the behavior of children and older people, the behavior of individuals with particular mobility restrictions/disabilities at these intersections was also examined[1)].

As a result, it was possible to observe and document prototypical characteristics and situations which, although of particular relevance for the safety of „vulnerable road users“, conceal safety risks for all road users. To conclude, recommendations for action were drafted and these were then discussed and validated in a workshop.

3 Analysis of the frequency and nature of accidents

The macroscopic analysis of the accidents was based on computerized accident data collected over several years in five federal states. In total, more than 350,000 accidents at intersections in and outside of built-up areas (excluding freeways) were recorded and analyzed. Of these, approximately 285,000 accidents (80%) occurred in built-up areas and some 65,000 (20%) outside of built-up areas (Figure 2).

Figure 2 shows the distribution of the examined accidents at intersections as a function of accident type. It shows that the following are the most frequent types of accidents at intersections:

(1) Turning into/crossing accidents (44% and 48%, respectively),
(2) Turning-off accidents (25% and 27%, respectively) and
(3) Accidents in longitudinal traffic (13% and 12%, respectively).

These three types of accident therefore account for 82% (in built-up areas) and 87% (outside of built-up areas) of all accidents at intersections, respectively.

1) The results of the observations of the behavior of people with particular mobility restrictions/disabilities were additionally extended by results reported by third-parties.

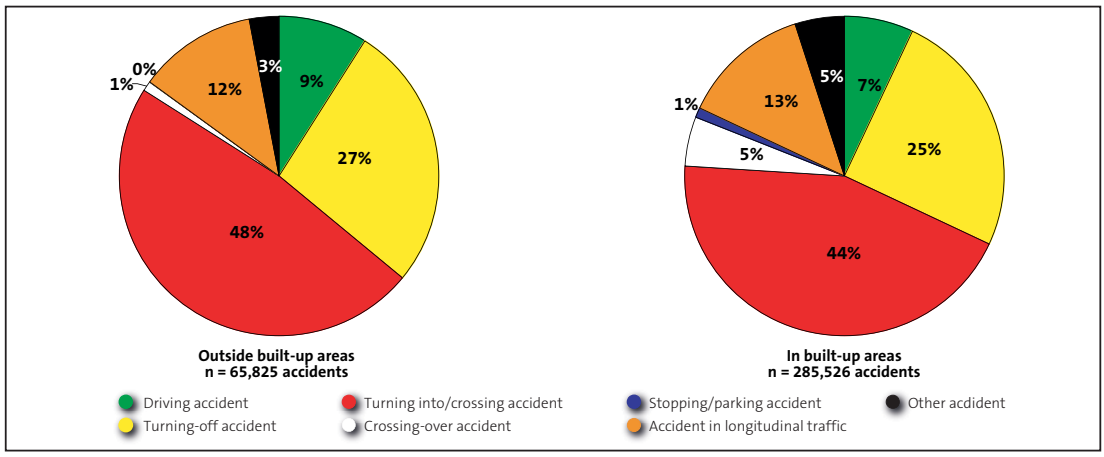

Figure 2:
Distribution of accidents at intersections by accident type

In the following in-depth analysis, the focus was placed on accidents in built-up areas. In addition, the distribution of three-digit accident types was analyzed on the basis of computerized accident data from the state of North Rhine-Westphalia for the period 2004 to 2008. The most common type of accident consists in the failure by road users who are turning left (across oncoming traffic) to respect the priority of through-traffic (accident type 211, Figure 3).

In accidents for which they are primarily responsible (as pedestrians and cyclists), children are mostly involved in turning-into/crossing accidents as well as crossing-over accidents, during the course of which they themselves are frequently injured[2]. In addition, they are also frequently injured in turning-off accidents in which they are involved without being primarily responsible. Among the three-digit accident types, accident type 342 (cyclists at junction joining from driver's right or nearside) was particularly prevalent in the case of children, followed by the two accident types 321 (cyclists after junction joining from right) and 301 (cyclists at junction joining from driver's left or far side) (Figure 3). In total, these three accident types in which children suffer injuries as cyclists, account for more than 20% of accidents in which children were involved[3].

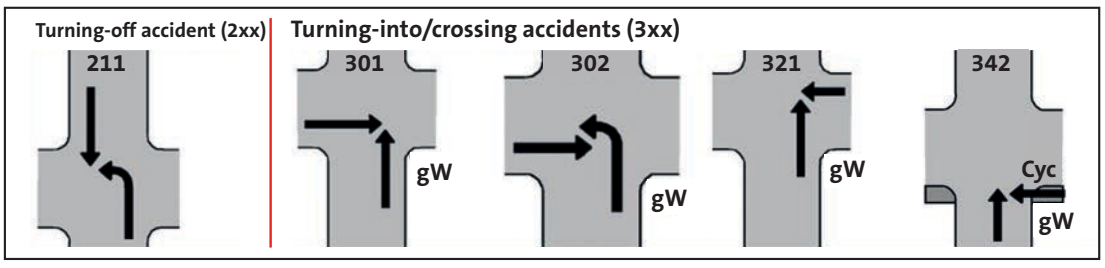

Figure 3:
Three-digit accident types (unranked extract)[4]

[2] Children are injured in the turning-into/crossing and crossing-over accidents which they cause as pedestrians or cyclists in more than 95% of cases.
[3] Detailed study of three-digit accident types based on the example of traffic accident data for NRW for the period 2004 to 2008.
[4] Figures taken from the M Uko accident type catalog, P. 48 ff. [3].

Older people primarily cause accidents as drivers. These accidents consist in particular of turning-off/crossing accidents and turning-into accidents. In the same way as children, older people are often injured as cyclists or pedestrians in turning-off, turning-into/crossing and crossing-over accidents in which they are involved without being primarily responsible.

Once again, in the group of drivers aged 65 years or more, accident type 211 is more common overall than the three-digit accident types corresponding to turning-into/crossing accidents. Besides accident type 211, older drivers were most likely to be involved in accident types 301, 302 and 321, as indeed was the case with all other drivers (Figure 3).

To summarize, the following applies to accidents at intersections in built-up areas:

- Children quite frequently cause turning-into/crossing accidents when cycling. These accidents primarily belong to the three-digit accident types 342 and 321. As pedestrians, they are disproportionately often the cause of crossing-over accidents.
- Within their age group, children are also frequently injured in turning-off accidents. As cyclists or pedestrians, they do not bear the primary responsibility for these accidents.
- As vehicle drivers, older people are most frequently involved in turning-off accidents (in particular of type 211) and turning-into/crossing accidents.
- Compared to other road users, children and older people are more frequently involved in crossing-over accidents, during which they are also injured.

Figure 4 provides an overview of the frequent (typical) accident types involving children and older people.

Under the current legislation governing road traffic accident statistics (the German Act on Traffic Accidents Statistics or StVUnfStatG), the criterion of „disability“ is not recorded. Consequently, it is not possible to perform a systematic, macroscopic analysis of computerized accident data concerning accidents involving people with restricted mobility. Only in a few cases (e.g. Berlin) is any indication of the presence of a disability among individuals involved in accidents recorded in the computerized accident.

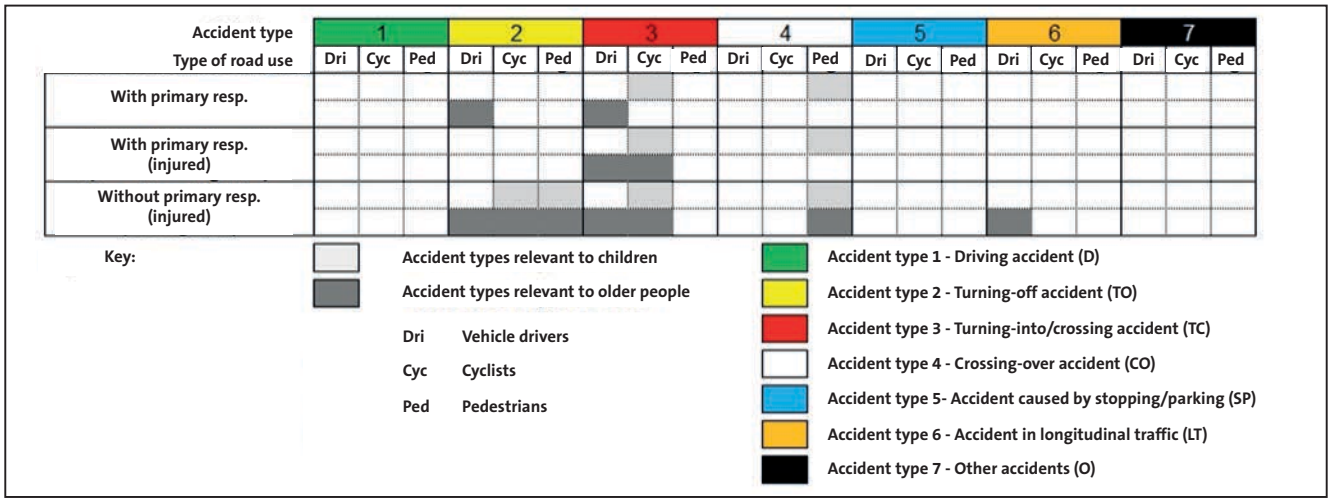

Figure 4:
Frequent accident types involving children and older people at intersections as a function of type of road use

The records from Berlin referred to a total of 63 accidents involving at least one person with impaired mobility for the period 2004 to 2010. Of these, 46 traffic accidents could be identified as occurring at intersections. In all cases, the overwhelming majority of these accidents (44) involved a wheelchair user. Almost three quarters of these 44 accidents (i.e. 33) occurred in conjunction with turning-off or turning-into/crossing operations.

The accident descriptions (not available for all the accidents) tend to indicate that the causes were

- absence of sight areas (driver claimed not to have seen the wheelchair user when turning off) and
- incorrect use of traffic areas (wheelchair users entered cycling facilities because of the lack of a curb ramp).

4 Safety analyses of selected intersections

At the methodological level, the safety analyses followed the procedure described for the safety auditing of roads [5] and were conducted on the basis of the planning documents made available (e.g. implementation plans, signal timing plans). In addition, each of the intersections was assessed during an on-site inspection. The municipal authorities were unable to provide planning documents for a number of intersections. In these cases, the study was primarily based on on-site inspections. The identified deficiencies were then subdivided into deficiency categories.

Figure 5 ranks these deficiency categories in terms of the number of intersections at which deficiencies belonging to the corresponding categories were identified. Only deficiencies that were still observed despite any modifications that might have been made to the intersection were taken into account. The results therefore describe the situation at the time of the on-site inspections.

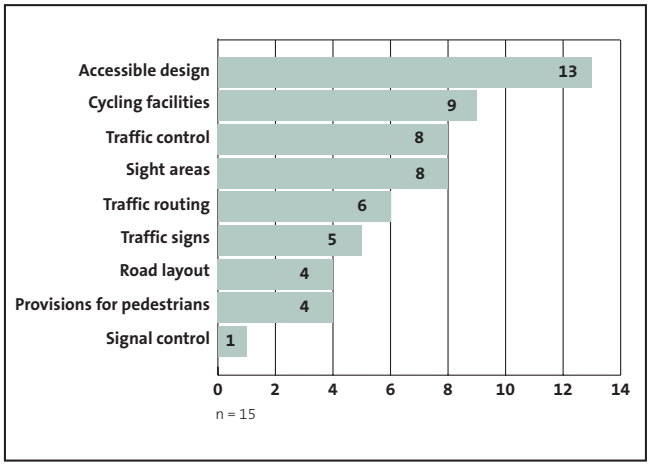

Figure 5:
Number of intersections with deficiencies for each category (n = 15 intersections, one intersection may be included in more than one category)

At nearly all the intersections (13 out of 15), the requirements of people with particular mobility restrictions (e.g. people with rollators or baby buggies) or impaired mobility (e.g. blind people or wheelchair users) were not or were only inadequately satisfied.

Facilities for cyclists were also either not implemented in accordance with the relevant guidelines or regulations or were completely absent[5]. Deficiencies in this respect were identified at nine of the total of 15 intersections.

Other frequently identified deficiencies related to shortcomings in the control or

5) Such cases were recorded as deficiencies if in circumstances where the recommendations on cycling facilities (ERA 2010 [4]) provide for protection lanes, mandatory cycle lanes or cycle paths, the corresponding facilities had not been implemented.

routing of motor traffic (e.g. lack of signal control for traffic turning left across the oncoming flow in situations of high traffic volumes and/or an absence of guidance in the area of the junction, traffic turning left and through-traffic in the same lane in the case of multi-lane approaches, removal of a lane immediately after the junction, no guide markings and/or wait markings at junction for traffic turning left).

Sight area deficiencies were identified at a total of eight of the 15 intersections (e.g. restricted field of visibility on approach, visual obstruction due to roadside green belt or stationary traffic).

5 Observation of behavior under real traffic conditions

The behavior of the road users was observed both by human observers and by means of a wireless camera system that was specially designed and produced for this research project.

The camera system consisted of four cameras (with transmitters), each of which was fixed to a stand, and a central receiver stand on which the receivers for all four cameras were mounted. The central receiver unit consisted of a hard disk recorder that was able to record the signals from all four cameras simultaneously.

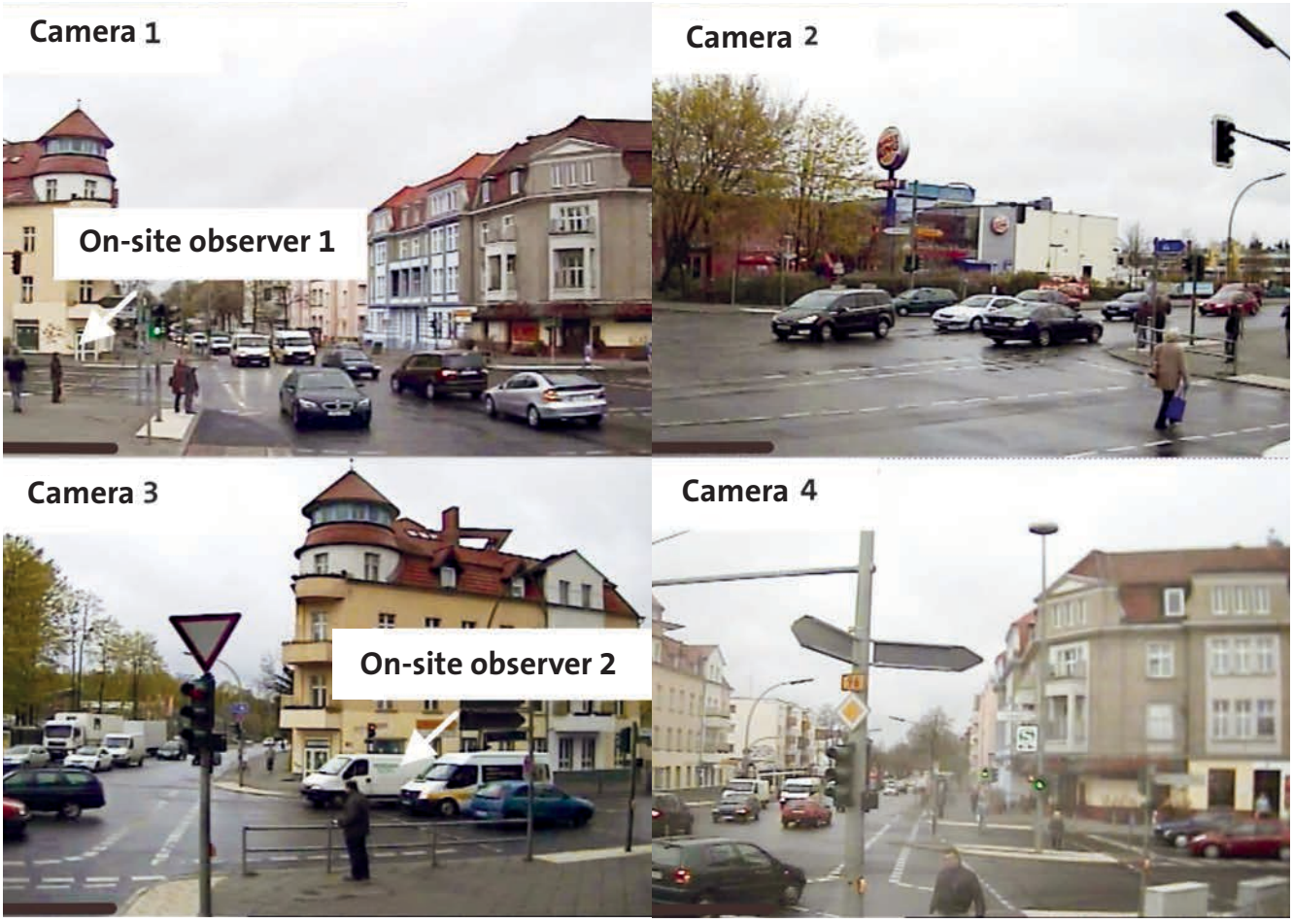

Figure 6:
Example of camera images taken from four different angles of view

The images recorded from the four cameras could then be perfectly synchronized and viewed simultaneously on a monitor during the subsequent assessment. If necessary, the images from a single camera were expanded to full-screen size for assessment purposes.

This approach made it possible to record the intersections from four different viewing angles (Figure 6).

The quantitative analysis of the behavior of the road users was then subsequently undertaken on the basis of the video images. The priority here was placed on determining whether the observed person (pedestrian, cyclist or driver) acted in compliance with the German road traffic regulations (StVO). The standards set out in the road traffic regulations were „strictly" applied. While the images were being recorded, the on-site observers estimated the age of each observed person and also assessed whether he or she presented any impairment to mobility. These on-site observers also made agreed signals that could subsequently be seen on the video recordings and be assigned to the observed road users.

In total, approximately 300 hours of video material was recorded at the 15 observed intersections and this was then evaluated in detail. As a result, the behavior of 24,598 individual pedestrians, cyclists and drivers was analyzed as a function of the age group to which they belonged and whether or not they had a mobility restriction/disability.

In general, all road users were found to comply to a large extent with the rules of the road. In the pedestrian and cyclist groups, children made relatively more mistakes than individuals belonging to other age groups (Figure 7 and Figure 8). In qualitative terms, both older and younger drivers made the same types of mistakes. However, older drivers made relatively more mistakes than younger drivers when turning left across the oncoming traffic (Figure 9).

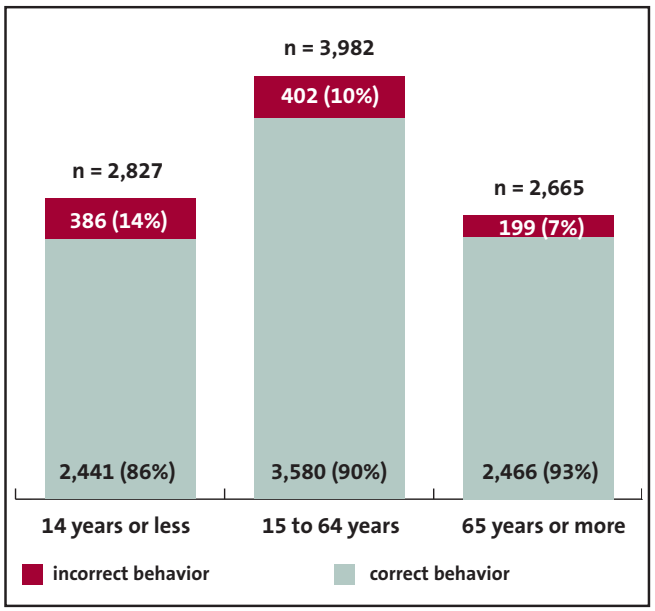

Figure 7:
Behavior of pedestrians as a function of age group

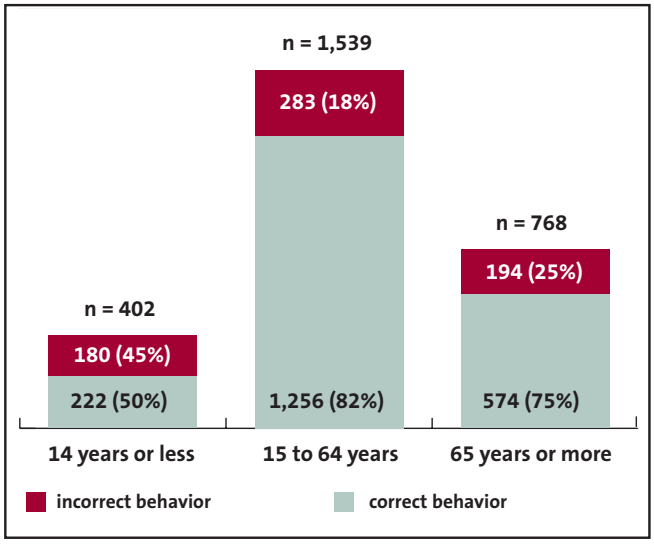

Figure 8:
Behavior of cyclists as a function of age group

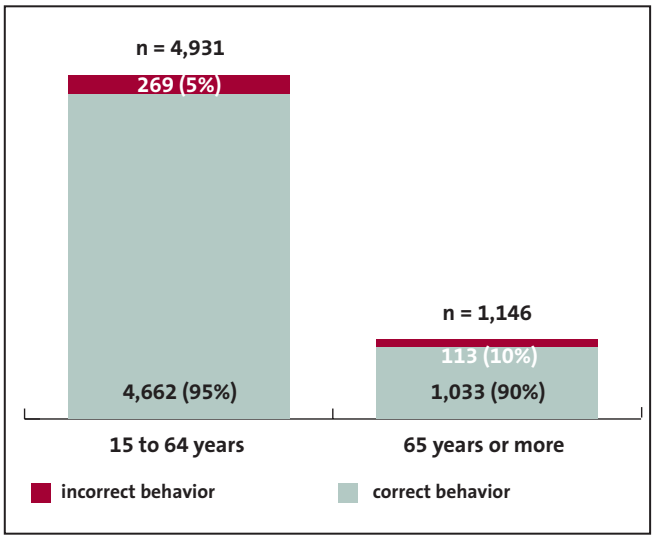

Figure 9:
Behavior of drivers (only when turning left) as a function of age group

6 Prototypical characteristics/ situations

On the basis of the accident analyses, plan audits, safety inspections and observations of road user behavior, it was possible to identify prototypical characteristics/situations in terms of type of intersection, traffic routing, traffic-related and construction facilities and measures as well as the associated behaviors as a function of type of road user and/or conflict situation. The prototypical characteristics and situations that lead to the main conflicts and sometimes result in accidents are listed below.

Prototypical characteristics/situations at intersections in general:

(1) Restricted sight contacts and restricted fields of visibility on approach (Figure 10, Figure 11)
(2) Absence of cycling facilities or cycling facilities not implemented in accordance with guidelines or regulations
(3) Absence of facilities for people with particular mobility restrictions (e.g. rollators, baby buggies) or mobility-related disabilities (e.g. people with severe visual impairment or walking disabilities) or such facilities not implemented in accordance with guidelines or regulations
(4) Unclear indication of priorities (vehicle drivers turning right / to the nearside into crossing pedestrians or cyclists) on right-turn lanes at which vehicles may turn irrespective of traffic signals (with/without pedestrian crossing or cycle path with priority at roads).

Figure 10:
Restricted fields of visibility on approach

Figure 11:
Impaired view for traffic turning left due to planted center strip and vehicles traveling in the opposite direction

Figure 12:
Accident chart at an intersection with no signal control for traffic routed left

Figure 13:
Worn-away/absent guidance and wait lines in junction (accident chart Figure 12)

Prototypical characteristics/situations particularly applicable to junctions with traffic signals:

(1) Traffic routed left but not signal-controlled (Figure 12, Figure 13)
(2) Absent or no longer recognizable traffic guidance (guidance lines, wait lines) for traffic turning left at junctions (Figure 13)
(3) Traffic merging into one lane or moving out due to the routing of traffic turning left and through-traffic on a single lane (when there is more than one lane on the approach road) or due to the removal of a lane after the junction (Figure 14).

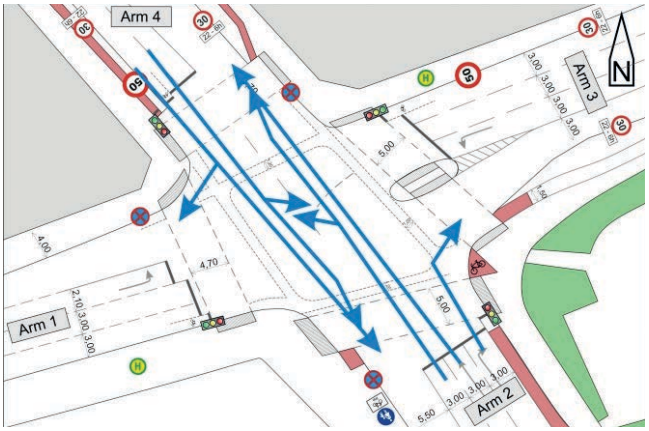

Figure 14:
Intersection with two-lane approach roads and single lane exit roads for through-traffic; traffic turning left and through-traffic permitted on the left-hand lane of each of the approach roads (traffic streams in one phase depicted in blue).

(4) Green arrow (German traffic sign 720) or lagging green for traffic turning left (if traffic turning left and through-traffic are permitted on the same lane) if there is a large offset between the stop lines at the approach roads.
(5) Long waiting times for pedestrians and cyclists, in particular in the proximity of schools or local public transport stops (violation of the RED pedestrian signal).

Prototypical characteristics/situations that occur in particular at intersections (crossroads and junctions) with traffic signs indicating priority:

(1) Absence of provisions for pedestrians or provisions not in accordance with applicable guidelines or regulations, in particular road-crossing facilities (Figure 15)
(2) Cycle path with priority not identifiable at joining road (Figure 16)
(3) Absence of road-crossing facilities for cyclists (cyclists use road-crossing facilities intended for pedestrians or use cycle paths/sidewalks in the direction opposite to the traffic flow).

Figure 15:
Absence of road-crossing facilities for pedestrians

Figure 16:
Unmarked (undetectable for vehicle drivers turning into and off the main road) cycle path priority (different views)

7 Recommendations for the design of intersections

Thanks to the extensive accident analyses and traffic observations, it was possible to verify certain factors that also represent a risk to vulnerable road users.

The study also revealed new insights, in particular concerning the behavior of older car drivers.

In general, it should be noted that many of the identified conflicts would probably not have occurred if the studied intersections had been designed in accordance with current design guidelines. Intersection design recommendations must therefore primarily refer to the indications given in current guidelines and regulations for the design of roads and intersections in built-up areas as well as for the design of pedestrian, cyclist and generally accessible road infrastructure. Such intersections must always be considered as a whole by taking account of the needs of all road users.

The resulting practical implications take account of the observed conflict situations involving children, older people and people with particular mobility restrictions/disabilities. Many of the design requirements necessary for these groups also apply to all other road users. Thus, for example, the observation of requirements in terms of sight areas and the creation of safe crossing facilities will help improve the traffic safety of children and wheelchair users in particular, but also that of other road users. Clear rules at junctions (e.g. safe routing of vehicles turning left, separation of traffic turning left and through-traffic) are particularly helpful to older people but also improve safety for road users of all ages.

8 Practical consequences

The study gives rise to the following main requirements:

(1) The obligation to implement separate phases for traffic turning left (across the oncoming traffic) should be made binding under

certain conditions, such as when traffic sight areas are restricted or traffic volumes are high. A corresponding, uniformly formulated requirement should be incorporated in the relevant design guidelines and regulations.

(2) There must be a binding requirement to guarantee respect for **traffic sight areas** during the planning of intersections and compliance with this requirement must be taken into account as early as the (preliminary) draft planning stage, for example by indicating sight triangles in the planning documents.

(3) Protected crossing places for pedestrians help improve road safety and, in particular, allow children, older people and people with restricted mobility to cross the road with minimum risk. To ensure accessibility, the crossing places should be designed with differentiated curb heights in order provide people with visual impairments with an edge that is perceptible to the feel as well as to allow wheelchair and rollator users to cross on level ground.

(4) When building new intersections or modifying existing ones, the design guidelines set out in current **design regulations** must obligatorily be adhered to. In these cases, intersections must be considered as a whole by taking account of the safety requirements of all road users. At the same time, the **safety auditing of roads** should be made binding at all design stages and for all roads.

(5) The **auditing of existing roads** should be introduced as a binding requirement when circumstances dictate (accident black spots) as a systematic element of local accident investigation. It is then essential that any measures to improve road safety resulting from the auditing of existing roads are implemented in practice.

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