The safety of pedestrian crossing.

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'No problem can be solved from the same level of consciousness that created it.'
Albert Einstein

Summary

More than half of all severe traffic accidents in which pedestrians or cyclists are involved, occur during road crossing. In this chapter insights, based on previous studies and literature, concerning requirements for safe and comfortable crossing facilities are discussed.

In order to develop notions of needs, abilities and motives, different pedestrian groups with similar physical and cognitive characteristics have to be defined. Research has shown that children under 11 and elderly above 75 years old are the most vulnerable pedestrian groups. Based on the development of cognitive capacities, such as attention, inhibition, planning and risk perception, in children a subdivision of four different age groups is proposed: children from 0 to 4 years old, children from 5 to 7 years old, children from 8 to 12 years old and children from 13 to 17 years old. Besides children, also people aged over 65 represent a vulnerable group of pedestrians, due to physical as well as functional constraints. In general elderly have a reduced physical fitness and -resistance, lower workload capacity and a reduced peripheral field of vision. Another group of pedestrians that deserve special attention are handicapped road users, either being physically or cognitively disabled. Whereas healthy adults are the least vulnerable, suboptimal situations in environmental design, crossing facilities and specific traffic circumstances may still create conditions that exceed the limits of normal human functioning.

Irrespective of the specific pedestrian group, good walking conditions are required to have people at least consider the option of walking. With respect to road crossing, it is especially relevant whether a crossing facility is safe and inviting (Convivial), comprehensible (Conspicuous) and whether facilities are sufficient in number and quality (Convenient). Since crossing involves a complex set of actions, providing pedestrians with crossing facilities can

reduce cognitive load. In general an unsignalised crossing is more dangerous than a crossing that is signalised with traffic lights. The presence of other crossing facilities, such as a median or a zebra can help to increase (feelings of) safety. Whether safety is actually increased by these measures, is dependent on many factors such as the facility's location, its visibility and traffic density. Besides general requirements, specific pedestrian groups have distinct preferences and needs. For example, a green light period should be adapted to the walking speed of older people or physically disabled people in order to make them feel safer. For younger people a relative short green light period causes impatience and therefore a higher risk potential. Therefore, in designing facilities for pedestrians, it is valuable to investigate which people will probably be mostly present.

In the final part of this chapter, conflict patterns and measures to reduce conflicts and accident severity are discussed. The most important conflict partner of the pedestrian is the car (65%). In the Netherlands 84% of all pedestrian accidents with severe injuries occur within urban areas. Whereas in an absolute sense, most pedestrian crashes occur in daylight, crash rates are higher during the night, when controlled for exposure and vehicle flow. Measures to reduce conflicts can concern measures on the behavioural level (education, public campaigns) as well as changes in traffic rules (speed limits), infrastructural design (separation of road users differing in mass, speed and direction and vehicle design (pedestrian-friendly car fronts, side-underrun-protection).

Based on above findings it can be concluded that the development of safe and comfortable crossing facilities first of all requires insights in pedestrian needs and abilities. Moreover, the specific needs of specific groups of pedestrians have to be taken into account. The benefit of such an approach is two-fold. To start with, gaining insight in these aspects makes traffic-engineers more conscious of the necessity to systematically meet pedestrian needs in our traffic system, in order to develop a safe and convenient pedestrian environment. Secondly, it provides us with concrete knowledge on which factors at which locations have to be taken into account when designing crossing facilities.

1. Crossing behaviour – the main problem

1.1. The challenge(s)

More than half of all severe traffic accidents in which pedestrians or cyclists are involved occur during road crossing (SWOV, 2006). In order to make crossing safer, it is important to define pedestrians' abilities and user needs. What are (different groups) of people able to do and what motives do they have as a pedestrian? This can eventually lead to more pedestrian friendly environmental planning and design. This is especially important since the value of systematically meeting pedestrian needs is often not yet recognized, whereas qualities or deficiencies of the physical environment are more intensively experienced by pedestrians than by other road users (Methorst, 2006).

1.2. Defining groups

Pedestrians vary widely in their physical and cognitive abilities. In order to gain insight in the requirements for safe and comfortable facilities for all, groups of pedestrians with similar physical and cognitive characteristics have to be defined.

Recently, it has been shown that children under 11 and elderly people above 75 years old are the most vulnerable groups of pedestrians (SWOV Factsheet, 2006). Age is an important criteria based on which pedestrian groups can be defined. Based on the developmental literature a subdivision in children of four different age groups is proposed in the present

report: children from 0 to 4 years old, children from 5 to 7 years old, children from 8 to 12 years old and children from 13 to 17 years old (SWOV Factsheet, 2006; Johansson & Leden, 2009; Methorst, 2003). The youngest group consists of children that are not able to participate safely in traffic on their own. Children in this age-category have not yet developed a proper 'theory of mind', that is pre-school children have a limited awareness of other's perceptions and intentions. If young children can see a person, for example a car driver, they tend to automatically assume that the other person can see them as well (Johansson & Leden, 2009). Moreover, risk awareness and attentional abilities are still low. Therefore, the most important factor for this group is the risk awareness of the parents; they need to stay around (Rosenbloom, Eliyahu & Nemrodov, 2007; Dunbar, Hill & Lewis, 2002). The second group, children from 5 to 7 years old, consists of children that are developing very fast in many ways. Whereas in some areas the child develops a grasp of logical concepts, they still show a tendency to focus attention on one thing while ignoring others. Despite an increased awareness of traffic in general, their risk awareness is not sufficient yet (Dunbar, Hill & Lewis, 2001 & 2002). Therefore they must rely on an adult, whose role is important for the child in learning the traffic rules. Mainly their capability of assessing what other road users will do is insufficient. These children often mostly walk in their own neighbourhood and are still mostly accompanied by an adult (Rosenbloom et al., 2007). This latter fact is what distinguishes them from the third group. This third group consists of children that are starting to participate in traffic independently. Despite between-individual variation, in general an important transition age concerning cognitive development is around 7 years of age, related to the development of so-called executive functions. One such cognitive function is inhibition. This enables a child to inhibit thoughts and actions in the service of other (more urgent) behaviours. Also planning abilities develop around this age. The further development of these high-level cognitive abilities in children between 8 and 12 years old enables them to participate more independently in traffic. Crossing the street is however a complex task, and children have not fully developed all the required abilities before the age of 11 or 12 (Johansson & Leden, 2009). Children this young age still have problems with assessing speed, direction and distance of moving vehicles. They tend to adopt the same distance gap when crossing the street, irrespective of the vehicle's speed. (Johansson & Leden, 2009). Children in the last group, with ages ranging from 13 to 17 years old, mostly travel independently. These children are vulnerable especially because they are susceptible for the opinions of their peers. Of all groups, they are most likely to imitate other road users, especially classmates. Consequently, the main reason for their vulnerability are attitudes and social motivations.

Also elderly people (65+) represent a vulnerable group of pedestrians, due to physical as well as functional constraints (Holland & Hill, 2007; Bernhoft & Carstensen, 2008). The fact that pedestrians are unprotected especially provides a disadvantage for the elderly because with age, bones get more brittle and elasticity of the soft tissues and muscle strength decline. This causes elderly in general being more severely injured than the young in crashes with equal collision energy (Wegman & Aarts, 2006). Whereas high variability may exist between people of the same age, in general elderly have a reduced physical fitness, resulting in earlier fatigue, lower walking speeds and reduced balance and flexibility. Moreover, lower workload capacity and a reduced peripheral field of vision, leading for example to problems in estimating speed of other traffic, induce their vulnerability as a pedestrian.

A different group of vulnerable road users are disabled road users. Disabilities can be divided into three different categories: mobility, sensory, and cognitive disabilities. Especially people using wheelchairs need more physical space in order to manoeuvre properly. Moreover, they are generally slower, have a smaller overview and are less visible for other road users. For people with visual, auditory or mental impairments also the way in which information is conveyed (modality, simplicity) at a crossing is of vital importance (see also the next paragraph).

1.3. Crossing facilities

Local and national governments promote walking because more transport by foot can benefit the environment and improves personal health. However, to increase the amount of walking, personal and environmental benefits are not sufficient. In order to have people consider the option of walking instead of other modes of transport, good walking conditions are required. 'Walkability' of a place can be characterized by the 5 C's (Transport for London, 2005), that is Connected, Comfortable, Convivial, Conspicuous, and Convenient. With respect to road crossing, the final three factors are especially relevant. Convivial means that walking facilities should be safe and inviting, that is pleasant to use. Conspicuousness relates to the important aspect of comprehensibility of walking facilities; crossing facilities should be clear and legible. Convenience concerns the degree to which crossing facilities fit the usability needs in terms of number and quality. Based on these criteria and on what we know about the functional abilities of different pedestrian groups, requirements for safe and convenient crossing facilities can be developed. The design of pedestrian (crossing) facilities should, whenever possible, be aimed at pedestrians with the lowest level of ability, or adaptable to specific (dis)abilities (e.g. dynamic traffic light duration) in order to ensure pleasant and safe conditions for all pedestrians.

Crossing the street involves a complex set of actions. The act of crossing requires a correct judgement of traffic speed and movement, traffic gaps and estimates of the time needed to cross. Providing pedestrians with crossing facilities can reduce this cognitive load, and consequently increase convenience and (sense) of safety, when crossing a road. Pedestrian crossings signalised with traffic lights are often used on busy roads with lots of traffic. The speed limit there for the motorised traffic is often higher than with unsignalised crossings (the latter ones are mostly in urban areas). Even though these types of intersections are signalised, 40% of all crashes involving pedestrians occur there (Tiwari, Mohan & Fazio, 1998). Waiting for the green light. is something pedestrians do not like very much. As a consequence, many violations occur that of course raise the risk of an accident (Bernhoft & Carstensen, 2008; Medina, Benekohal & Wang, 2007). In this case, decreasing the waiting times for pedestrians could help. This can be done for example by giving priority to pedestrians (e.g. by providing them the green light more often), but also by reducing the crossing distance and by keeping the traffic light green longer for pedestrians (SWOV Factsheet, 2006).

An unsignalised crossing is often more dangerous than a crossing that is signalised with traffic lights. The pedestrian needs to trust his own perception and risk awareness to get to the other side of the road safely. There are differences in the degree of safety nevertheless. An unsignalised crossing with a median (so pedestrians can cross the street in two phases) is less dangerous than a crossing without a median (SWOV Factsheet 2005). After all, in this first case, the pedestrian has the possibility to concentrate on the oncoming traffic twice. However, when pedestrians have no priority on a crossing, the situation is still not safe enough. A zebra crossing, for example, is meant to help pedestrians in crossing the street faster and safer; the oncoming traffic is expected to wait. The mere presence of a crossing facility (such as zebra markings) does however not automatically imply increased safety. Reality learns that many pedestrians often do not use the zebra crossings and that drivers do not always stop for pedestrians that do use them (SWOV Factsheet, 2006). One reason could be that pedestrians do not trust the oncoming traffic enough and consider these zebra crossings and crossings without priority equally (un)safe. For this reason, walking a bit further to use a zebra crossing is not worth the effort for pedestrians. Another reason can be the visibility of zebra crossings, for pedestrians as well as car drivers. Zegeer, Stewart, Huang & Lagerwey (2001) investigated pedestrian crashes at 1.000 marked crosswalks and 1.000 matched unmarked comparison sites. None of the sites in this study had a traffic signal or stop sign. The authors found that in case 24 hour traffic volume was less then 10.000 vehicles, safety levels were equal for locations with crossing facilities (markings, such as a zebra) and without any facilities. However, when traffic volume was larger, locations without

any marking turned out to be safer. This might have to do with the fact that in dense traffic, car-drivers do not notice the markings. Also other research has shown that unmarked crosswalks on multilane roads with high average daily traffic scores are safer (i.e. less crashes) than marked crosswalks on the same road types (Shurbutt, van Houten & Turner, 2007).

As such it is very important to consider the context, such as traffic density, before implementing specific crossing facilities. (Sense of) safety is very important in this respect. A measure that is already used to increase pedestrian safety is to place the zebra crossings on or just after a plateau. By doing so, the oncoming traffic is forced to reduce speed, which also draws the attention of the driver (SWOV Factsheet, 2006). The latter consequence might lead to a higher chance of perception of pedestrians who are about to cross. Another important issue is the extent to which crossing facilities are recognizable for drivers and pedestrians When crossings in general are made more uniform and recognisable, this will also increase safety (SWOV Factsheet, 2005).. Different designs and layouts may cause a lack of clarity which can lead to reduced understanding and consequently unsafe behaviour. Pedestrian crossings should therefore be more standardized and should be on places where the sight for the driver is good (e.g. not directly after a curve). Based on a study into safety related characteristics of 121 crossing facilities in the Netherlands, De Langen (2003) concluded that crossing facilities in the Netherlands lack uniformity. Nevertheless, even with zebra-marks or signals, crossing a road with six lanes will never feel safe and comfortable. In such settings, pedestrian paths below or above street level would be good alternatives

Besides the average pedestrian, specific pedestrian groups have different abilities and consequently have distinct preferences and needs. Children younger than 11-12 years have not yet developed all the necessary cognitive abilities and their risk awareness is insufficient in order to cross a road safely on their own. Ideally, at locations with many young road users, such as schools or playgrounds, motorized traffic has to be kept out as much as possible. In case this can not be realized safe circumstances have to be created in which children are assisted in crossing the road by school crossing patrols and car drivers are especially aware of the fact that children can dart out into the street. Crossings and signalised intersections are often better appreciated by older than by younger pedestrians (Bernhoft & Carstensen, 2008). Younger pedestrians do not necessarily notice when these facilities are missing, they tend to care more about moving fast and directly in traffic and do not like to wait or stop. Especially younger men tend to neglect the use of pedestrian facilities (Kim et al., 2007). Older pedestrians, on the other hand, often experience doubts about their own abilities, which in turn causes them to be more cautious in specific traffic situations (Holland & Hill, 2007; Bernhoft & Carstensen, 2008). The extent to which they experience the need to be safe and have respect for the law is therefore higher than for younger pedestrians. That is why they often plan their route through town according to the presence of pedestrian facilities. Practically, this means that in designing crossing facilities for pedestrians it has to be investigated which people will probably be present. In dense traffic, light signals are appreciated especially by older people because they experience difficulties in perceiving when a gap is sufficient enough for them to cross the street. One other, very important topic is the green light period. This period should be adapted to the walking speed of older people or physically disabled people in order to make them feel safer (Bernhoft & Carstensen, 2008). For the same reason crossing distances should not be too long. Otherwise, they might feel as if they have to hurry to be able to get to the other side of the road in time, which might cause unsafe behaviour (i.e. higher walking speed, causing more risk of falling). For younger pedestrians, a short green period causes impatience and therefore a higher risk potential (Bernhoft & Carstensen, 2008). In the Dutch city of Tilburg, a study was performed to investigate what factors are causing the percept of “short green time” (Godefrooij, 2008). What was found is that for many pedestrians their feeling of danger causes them to indicate perceived green times as too short. It has been shown that many people are only able to cross the street to the centre median strip in the available green time. The fact that the

median strip is narrow and unsafe is shown to be an important factor for the percept of short green time. Furthermore, people are not always sure how much time is left for them to cross before the cars will start driving when the light has become red during crossing. A new type of traffic light has been introduced in Tilburg, which displays both waiting time and crossing time. This approach reduces the uncertainty of pedestrians to a great extent.

Other important issues concerning crossing facilities are the spatial layout as well as the walking surface. The walking surface should be even to prevent falling for older or physically disabled people and make it more convenient for younger people as well, since they (at least to some extent) can walk faster on an even surface than on an uneven surface (Bernhoft & Carstensen, 2008; SWOV Factsheet, 2005). Also the spaces in which pedestrians can comfortably manoeuvre differ. A width of 1 m is adequate for people with ambulant (using crutches or a walking frame) disabilities whereas a wheelchair requires at least a clear width of 1.2 metres. Also stable, even surfaces with no rapid change in slope are required for mobility impaired people as well as for visually impaired pedestrians.

Besides the architecture, the information conveyed to pedestrians at pedestrian crossings should be clear. Ideally, the design of a crossing should be intuitive, not requiring too much extra information to explain its use. However in some cases, providing extra information is necessary. In these cases information has to be simple, universal and very well visible. For people suffering from visual impairments should be provided with tactile cues or signs, whereas clear visual signs and long sight distances free of visual obstructions are very helpful for people suffering from hearing impairments. For mentally disabled pedestrians clear pictures, symbols and colours, instead of words, can be used to convey information.

2. Conflict and accident pattern

2.1. General overview

In the Netherlands the most important collision partner of the pedestrian is the car (65%). Whereas large trucks, busses and trains are involved in few accidents with pedestrians, they have a relatively large share in the number severely injured pedestrians who do not survive (SWOV Factsheet, 2006). Pedestrian safety is, as in other countries, determined by the amount of motorized traffic, which is still growing every year. Pedestrians are very vulnerable simply because they are without vehicle and are thus lacking a shell to protect them. For example, in the EU countries pedestrians are on average 6.7 times more likely to be killed in a traffic accident than vehicle occupants, whereas motor-vehicle accidents with pedestrians (and bicyclists) constitute a relative small proportion of the total amount of crashes (Shinar, 2007). In addition to the lack of protection, pedestrians are vulnerable because of large mass and speed differences with other road-users. Most accidents take place when crossing a street. The time pedestrians spend on crossing streets might therefore be considered as a valuable measure when defining a pedestrian risk factor (Shinar, 2007).

2.2. Location and time of conflicts

In the Netherlands, research has shown that 84% of all pedestrian accidents with severe injuries occur within urban areas, due to a large road-user density within these areas which bring about an increased likelihood of a conflict (SWOV, 2006).

Within these urban regions specific locations can be considered as especially risky regarding pedestrian accidents. Locations with vulnerable road users (such as schools or locations where many elderly cross the street) are areas which require special attention. Also specific hours of the day, on which traffic intensity is high or visibility is reduced, might be more risky

for pedestrians. Whereas in an absolute sense most pedestrian crashes occur in daylight, crash rates are higher during the night when controlled for exposure and vehicle flow (Shinar, 2007). Low visibility of pedestrians during night time appears to be the most important cause. Probably for the same reason accident rates differ between seasons. For example in the US, September through January, months with typically fewer daylight hours and more bad weather conditions, show the highest numbers of pedestrians fatalities. Fatal accidents with children are greatest in May-July, probably related to in increase in outdoor activity during the summer. Age and time of day may also interact when considering pedestrian crash rates. In some age groups most accidents happen on specific times of day. For example in the Netherlands data show that within the group of young pedestrians (0 -14 yrs) accidents which lead to severe injuries mostly find place between 16.00 and 18.00 hrs (SWOV, 2006). These findings may relate to playing behaviour during these after-school hours. According to analyses by Sentinella and Keigan (2005) most pedestrian accidents in which children are involved occur when children are playing rather than on the way between home and school. Findings indicate that young children are unable to properly focus on traffic while involved in other (playing) behaviour (Shinar, 2007).

2.3. Measures to reduce conflicts (severity)

Infrastructure and separation
Besides design considerations of crossing facilities, measures to make pedestrian road crossing more agreeable and safe can also concern measures on the behavioural level as well as changes in traffic rules and infrastructural- and vehicle design. A very effective measure in this respect is the separation of road users who differ in mass, speed and direction, which can prevent severe collisions with vulnerable road users.

Speed limits
In case it is impossible to separate different road-users, speed limits should be introduced which reduce the impact of potential collisions. International research has shown that driving speeds higher than 30 km/hr drastically increase the probability of a pedestrian being killed in case of a collision (SWOV, 2008). Introducing speed limits does not automatically imply that drivers stick to these limits. Other measures, such as speed bumps, could ‘force’ drivers to adjust their speed.

Vehicle design
Another way to prevent or reduce the impact of accidents is to introduce pedestrian-friendly car fronts, that is taking into account in car design the location at which pedestrians hit cars (Wegman & Aarts, 2005) as well as the removal of sharp and inflexible parts (SWOV, 2006), in order to reduce the severity of pedestrian injuries in case of an collision. Also large vehicles should be equipped with side-underrun-protection as well as good side and rear view.

Driver and pedestrian education
Besides environmental- and vehicle design an important factor in pedestrian-vehicle conflicts is of course both driver and pedestrian behaviour in traffic. During driving lessons aspirant drivers should be informed and educated on safe driving behaviour, also specifically in relation to pedestrians. Also public campaigns can aim at making drivers as well as pedestrians more aware of safe and unsafe behaviour. Behavioural interventions concerning pedestrians are especially targeted at children. Children up to 12 years old are likely to be involved in accidents because they suddenly dart into the street. In general children younger than 12 do not have yet adequate crossing behaviour. Despite the fact that from around ten years old they do already know the safety rules, they are often not able to apply these rules in daily practice (Shinar, 2007). It is therefore important to provide age-appropriate education and practice on schools. For this age group also school crossing patrols might be an effective measure to increase safety. Also parents should be encouraged to educate their

children on safe crossing behaviour. Research has however shown that children show more dangerous crossing behaviour when accompanied by an adult than when alone or with other children. An explanation might be that they simply trust on the adult and therefore do not pay much attention to the road (Rosenbloom et al., 2007). Older teenagers generally do have safe crossing skills, but they do not always apply them. This is suggested to be related to a tendency to increased risk seeking and insufficient self-regulation in adolescents (Steinberg, 2004). Therefore education for this group of children should not be focused at crossing skills but at learning about the consequences of their behaviour.

The findings and insights described in this chapter show that the development of safe and comfortable crossing facilities first of all requires insights in pedestrian abilities. Before defining a crossing facility in terms of the environmental requirements, the capacities and limitations of its users have to be taken into account. Consecutively, in terms of Conviviality and Convenience, the specific needs of different groups of pedestrians have to be considered. The benefit of such an approach is two-fold. To start with, gaining insight in these aspects makes traffic-engineers more conscious of the necessity to systematically meet pedestrian needs in our traffic system, in order to develop a safe and convenient pedestrian environment. Secondly, it provides us with concrete knowledge on which factors at which locations have to be taken into account when designing crossing facilities.

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