SWOV Fact sheet

Types of junctions

Summary
In the Netherlands, 44% of all seriously injured road crash victims sustain their injuries in crashes at junctions, and more than two-thirds of those occur in urban areas. There are numerous kinds of junctions in the Netherlands. According to Sustainable Safety the number of junction types needs to be limited, depending on the types of roads that intersect. The desired types of junctions do not always correspond with the recommendations in the design manuals. The types of junctions needed according to Sustainable Safety should be determined by making allowance for potential conflicts and differences in mass and speed that may occur at certain types of junctions. Where conflicts are unavoidable it is important to reduce their severity by reducing speed. With a speed limit of 30 km/h, slow and fast traffic may use the same space, but at higher speeds this is no longer permissible. Uniformity of junction types will increase their recognizability for road users and is more likely to bring about the desired style of driving.

Background
Of all recorded road traffic casualties (fatalities and in-patients) in the 2005-2007 period in the Netherlands, 44% occurred at junctions. This fact emerges from Dutch road crash registration (BRON, Ministry of Transport, Public Works and Water Management). More than two-thirds of these casualties occur at urban junctions and slightly less than one-third at junctions outside the urban area. This factsheet examines the different types of junctions built in the Netherlands within and outside the urban area. The road safety of these junction types is examined in different ways, i.e. through a comparison of types of junctions and through an examination of the factors that can make junctions (sustainably) safe. The focus is mainly on junctions between access roads and distributor roads, junctions between two access roads and those between two distributor roads. Roundabouts, junctions between through roads and distributor roads and those between two through roads are dealt with to a lesser extent.
For more information about roundabouts we refer to the SWOV fact sheet *Roundabouts*. More information about access roads, distributor roads and through roads can be found in the fact sheet entitled *Background of the five Sustainable Safety principles*.

What types of junctions occur in the Netherlands?
There are different types of junctions in the Netherlands. Guidelines exist for when a certain type of junction should be used and how the junctions should be designed. For situations within the urban area these guidelines have been published in the *ASVV* (CROW, 2004). Guidelines for junctions outside the urban area can be found in the Road Design Manual (CROW, 2002).
Various layouts of junction types are possible: four-arm junctions are seldom identical. This may be due to the traffic situation or the cost of the available space, but may also stem from the non-prescriptive nature of the guidelines. The guidelines are recommendations, not formal directives. Therefore, the road managers are not obliged to adopt them partly or in full. Consequently, the uniformity of junctions is not guaranteed. It is not known to what extent road managers adopt the recommendations. Non-uniform junctions can be identified through road safety audits and inspections. These tools are used to test the road infrastructure for its road safety. For more information about this matter we refer to the SWOV fact sheet *The Road Safety Audit and Road Safety Inspection*.
What the Dutch guidelines describe as the ideal situation and/or as sustainably safe does not always correspond with SWOV's Sustainable Safety principles. In the section headed *What makes a junction (sustainably) safe?* we discuss the types of junctions according to Sustainable Safety. First, we will look at the types of junctions described in the guidelines.

Urban junctions -- based on ASVV (CROW, 2004)
A junction between two access roads can be designed as a roundabout or as a junction with three or four-arms. The junctions have no designated priorities (traffic coming from the right has right of way). Physical speed reduction measures may be included. A junction between an access road and a distributor road can be designed as a junction with an exit construction, a T-junction or a single lane

roundabout. The crossing of two distributor roads can occur on a single-lane or multi-lane roundabout.

Rural junctions -- based on the Road Design Manual (CROW, 2002)
Junctions between access roads may be designed as junctions without designated priorities. A junction with designated priorities, for example with traffic signs, can be used if desirable, for instance because the junction is inconspicuous. When there is a junction of an access road and a distributor road, the right of way on the junction is regulated with a priority scheme. The distributor road is then the road with the right of way. On a junction between two distributor roads three types of junctions are possible: a roundabout, a junction with a priority scheme and a junction with traffic lights. For road safety reasons a roundabout is preferable. If vehicles cross a junction at a speed higher than desirable, it is possible to install speed-reducing measures. Later in this factsheet we will look in more detail at speed-reducing measures.

When and how are traffic lights used at junctions?
At some junctions and roundabouts it is possible to regulate traffic by means of a Traffic Control System (TCS). This often happens if the situation without traffic lights does not function optimally. The waiting time - i.e. the time somebody must wait in order to cross the junction - can be very long, for example, thus causing traffic flow problems at the junction. A well-designed traffic control system produces a fair time division for road users and can give public transport priority (CROW, 2004). Traffic lights time-separate traffic. They ensure that the two conflicting directions at the junction in *Figure 1* do not simultaneously get green or amber, for example. Additionally, there is sufficient time between the end of the amber phase of one conflicting direction and the start of the green phase of the other conflicting direction. This is also known as the clearance time (CROW, 2006).

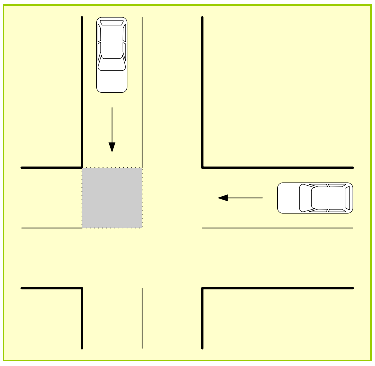

Figure 1. *Conflicting directions and their conflict area at a junction*.

Traffic lights do not generally improve road safety (Ogden, 1996, in Hummel, 2001). This is because the traffic is separated by time and not place, so crashes may still occur if vehicles ignore red lights. As the speed in such violations tends to be high, it results in a serious conflict. Moreover, there is a greater likelihood of rear-end collisions (CROW, 2004).

There are three criteria for installing a TCS (CROW, 2002): intensity, lost time and lack of safety. The traffic intensities, lost times and crash patterns determine whether a TCS is necessary.
A TCS has several possible settings: fixed-time, semi-fixed-time, vehicle-actuated and traffic-actuated. Vehicle and traffic-actuated signals automatically adjust to the traffic that is present (motor vehicles detected by traffic detectors). A traffic-actuated TCS makes allowance for all traffic present (the traffic volume); but this type of signal is rarely used in the Netherlands (CROW, 2006). Fixed-time signals function according to a fixed time schedule, while semi-fixed time signals are a combination of fixed-time and vehicle-actuated signals. The situation determines which type of signal can best be chosen. There are countless possibilities for regulating slow traffic. Non-conflicting parallel cycling directions can get the green light at the same time as motorized traffic. Similarly, all cyclists can get the green light at the same time, while the other traffic gets red (CROW, 2006). The safety effects of the different signal schemes are not known.

What if we compare the safety of different types of junctions?
The lack of safety at a junction is generally expressed in the number of crashes per number of crossing vehicles (intensity). This is referred to as the junction risk. Various studies have been conducted into the safety of different types of junctions within and outside the urban area. Many are

comparative studies that say nothing about the road safety effects of different types of junctions. For such pronouncements it is necessary to conduct before-and-after studies that compare the road safety of a location before and after a certain measure (including layout) has been taken.

Urban junctions
Janssen (2004) calculated risk values of different types of urban junctions in a comparative study. The study revealed that there is a lower risk:
– on roundabouts compared with junctions;
– on three-arm junctions compared with four-arm junctions;
– on junctions without traffic lights compared with junctions with traffic lights;
– on junctions without right of way compared with junctions with right of way;
– on junctions without cycling facilities compared with junctions with a separate bicycle path.

The differences in the risk values may not be interpreted as the effect of features in which these junction types differ from each other, however. For that reason the study conducted by Janssen (2004) cannot and may not be used as a reason for rearranging types of junctions that get an ‘unsafe’ score into 'safer' scoring junction types.
Let us take the last finding as an example. The study shows that junctions without cycling facilities have a lower risk than those with a separate bicycle path. This appears to be counterintuitive. But in this case two different situations are being compared: junctions where a bicycle facility is apparently necessary and junctions where such a facility is unnecessary. Research has been conducted only into the main features without looking at the other features of the junctions and the same applies to the structure and function of the road network of which they form part. In other words, Janssen did not investigate whether a change to the situation actually increased road safety; this can only be determined by means of before-and-after studies.

Jansen (2004) also examined the relationship between crashes resulting in injury and traffic volumes on junctions of through-roads with a speed limit of 50 km/h. *Figure 2* shows that the number of injury crashes often increases with increasing traffic volume. However, the exact relationship differs for different types of three-arm and four-arm junctions.

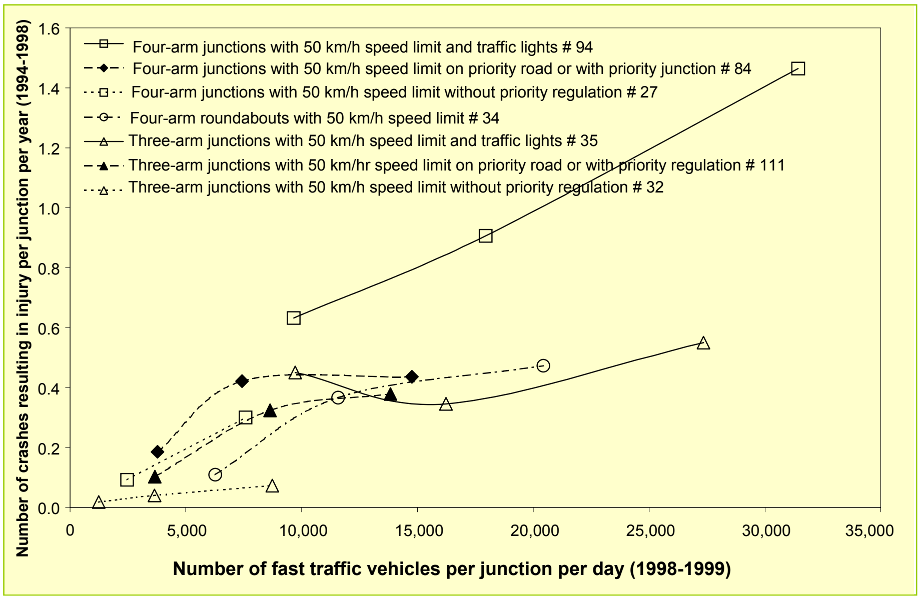

Figure 2. *Relationship between number of injury crashes and traffic volume on three and four-arm junctions of urban through-roads with a 50 km/h speed limit. The # sign stands for the number of junctions of that particular type (Janssen, 2004).*

Rural junctions
Beenker (2004) carried out a before-and-after study into the layout of 60 km/h zones. This showed that the number of crashes with casualties at junctions in 60 km/h zones decreased by 47% compared with the situation before the 60 km/h layout. A comparative study at network level revealed that roundabouts and staggered junctions are safer than four-arm junctions (Hummel, 2001). A staggered

junction is a variant of a four-arm junction, with the junction divided into two three-arm junctions. This precludes transverse conflicts. Hummel based his research on statistics from the United States and various European countries. In Finland the safety of three-arm and four-arm junctions outside the urban area was investigated in a before-and-after study (Kulmala, 1995). This showed that 1.3 to 1.4 times more crashes occurred on four-arm junctions than on three-arm junctions. Other international studies (including comparative studies) also showed that four-arm junctions are less safe than three-arm junctions and that roundabouts are safer than 'ordinary' junctions (Elvik & Vaa, 2004; O'Cinneide & Troutbeck, 1995). A before-and-after study by Corben et al. (2007) showed that the construction of staggered junctions reduced the number of serious crashes. According to Corben et al., however, staggered junctions do not fit in entirely with a safe traffic system because they are not forgiving enough for road users, particularly in situations with high speed limits. While transverse conflicts are avoided, a number of other potential conflicts will remain.

What makes a junction (sustainably) safe?

In safety terms what matters is the number of points in a junction at which road users may possibly come into conflict with each other. The fewer the potential conflict points, the safer the junction will be. That is one of the reasons why roundabouts are safer than junctions. This can be seen in *Figure 3*: from left to right the number of conflict points increases on the different types of junctions.

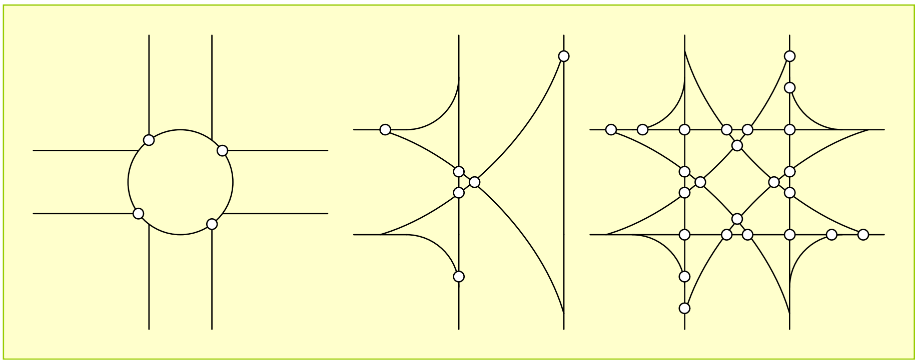

Figure 3. *Conflict points on a roundabout, three-arm junction and four-arm junction.*

The purpose of the Sustainable Safety vision is to prevent crashes and, where this is not possible, to rule out almost entirely the likelihood of severe injury (Wegman & Aarts, 2006). It follows from this view that certain encounters between road users at junctions must be ruled out. These are encounters between road users with marked differences in terms of speed and mass; these can result in serious conflicts. In the case of a collision between a car and a pedestrian, i.e. with a large difference in mass (and protection), the likelihood of the pedestrian being killed increases enormously at collision speeds above 30 km/h (see *Figure 4*).

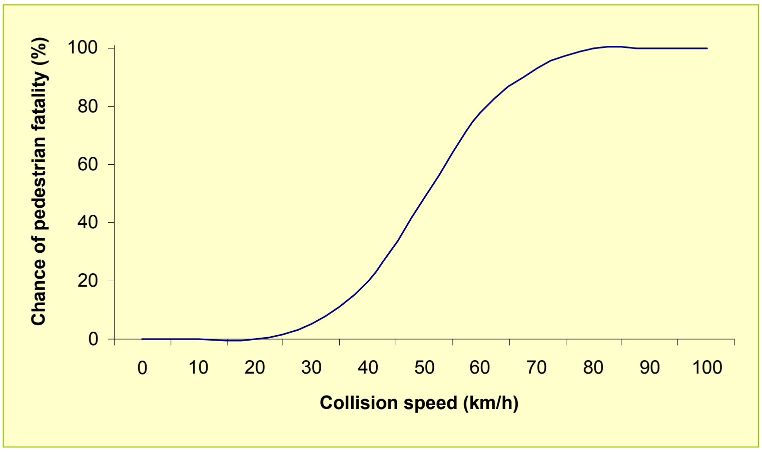

Figure 4. *Probability of a pedestrian fatality in a collision with a car as function of the collision speed (Ashton & Mackay (1979) in Wegman & Aarts, 2006).*

Where conflicts are unavoidable, it is important to reduce their severity by adjusting the speed limit. *Table 1* shows the safe speed limits for encounters between certain types of road users. It can be seen, for example, that 30 km/h is the safe speed limit for encounters between fast and slow traffic.

Road types in combination with allowed road users	Safe speed limit (km/h)
Roads with possible conflicts between cars and unprotected road users	30
Junctions with possible transverse conflicts between cars	50
Roads with possible frontal conflicts between cars	70
Roads with no possible frontal or transverse conflicts between road users	≥100

Table 1. *Proposal for safe speed speed limits for cars, given possible conflicts between certain types of road users (Tingvall & Haworth (1999) in Wegman & Aarts, 2006).*

Safe speeds can be brought about by infrastructural measures. At junctions physical speed-reducing measures such as roundabouts, speed humps and raised junctions could be constructed. The table below shows the various measures that should be taken for particular types of junctions. For more information about speed management we refer to the SWOV fact sheet *Measures for speed management*. Additionally, the desired driving speed can be evoked by consistency and continuity in design. This will ensure that road users recognize the types of roads and junctions and know what is expected of them (Wegman & Aarts, 2006).

Which types of junctions are desirable according to Sustainable Safety?
Sustainable Safety makes a distinction between 'normal' junctions and roundabouts (Wegman & Aarts, 2006). Sustainable Safety prefers the roundabout, not only because of the smaller number of conflict points compared with junctions (see *Figure 3*), but also because the passing speed is lower, which means the consequences of a potential conflict are not serious. Junctions should preferably not be regulated by traffic lights, because ignoring a red light can produce very serious conflicts due to the high driving speed.
For junctions between different types of roads, Sustainable Safety has drawn up a preferred type of junction (CROW, 1997; Van Schagen et al., 1999); these are shown in *Table 2*. For each type of junction *Table 2* indicates whether a right of way and/or speed-reducing measure needs to be taken. The ideal situation recommended in the Dutch guidelines (CROW, 2002; 2004) does not always correspond with the Sustainable Safety vision.

Location	Crossing between	Desired type of junction	PM	SRM
Within the urban area	AR and AR	At-grade junction	-	Yes
	AR and DR	At-grade junction	Yes	Yes
	DR and DR	At-grade junction	Yes	Yes
Outside the urban area	AR and AR	3-/4-arm junction with raised crossing section (raised junction)	-	Yes
	AR and DR	3-/4-arm junction with raised crossing on distributor road before and after the junction (or possibly roundabout)	Yes	Yes
	DR and DR	Roundabout and other raised junctions, 100 m before and 100 m after the junction	Yes	Yes
	DR and TR	Grade separated junction	Yes	-
	TR and TR	Interchange	-	-
AR= access road; DR = distributor road; TR = through-road; PM = priority measure; SRM = speed-reducing measure.				

Table 2. *Overview of advisable junction types according to Sustainable Safety (based on Van Schagen et al., 1999).*

Through-roads are only for motorized traffic, which must be able to drive safely at high speed. Junctions with through-roads must therefore be grade separated. Nor may slow traffic be present on connections with through-roads. On distributor roads there can be large differences in mass, such as between motor vehicles and pedestrians/cyclists. Therefore, at these junctions (at-grade) the speed differences will need to be minimized. The same applies to access roads. For information about facilities for cyclists and pedestrians we refer to the SWOV fact sheets *Crossing facilities for cyclists and pedestrians* and *Bicycle facilities on road segments and intersections of distributor roads*.

Conclusion

There are numerous types of junctions in the Netherlands. According to Sustainable Safety, however, a limited number of junction types for intersections between different road types is preferable. These preferred types of junctions sometimes differ from the recommendations contained in the Dutch design manuals. The preferred junction types in Sustainable Safety make allowance for safe speeds to avoid serious conflicts, transverse conflicts and frontal conflicts, or in any event to reduce the severity of the consequences. With a speed limit of 30 km/h, slow traffic and fast traffic may be allowed to use the same space. At higher speeds, this ceases to be permissible. It is recommendable that uniformity of junction types be pursued, so that they may be easily recognized by road users. This may help to evoke the desired driving style.

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