DIPLOMARBEIT
Master Thesis

# Curb Extensions at Unsignalised Crossings

## Evaluation of guidelines

ausgeführt zum Zwecke der Erlangung des akademischen Grades
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unter der Leitung von

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## Abstract

Curb extensions improve the visibility of pedestrians and vehicles on streets with on-street parking. They shorten the crossing distance and provide a secure waiting area for pedestrians.

In the first part of this thesis, the national guidelines of Austria, Germany and Switzerland about curb extensions at non signalized crossings are compared.

In the second part, 100 existing curb extensions in Vienna are reviewed in order to identify the main problems, where the required sight distances are not achieved; which was the case in 81 of the 100 sites. Most of the recorded curb extensions did not reach out to the lane, but were smaller than the adjacent parking lane. Many would have reached the required sight distances if they were extended to the lane.

In a next step, pedestrian behaviour was observed by a video analysis to evaluate the approach of the guidelines of how to design curb extensions. The stopping points of pedestrians were recorded and set in relation to both, the curb an the lane. The distribution of stopping points did not focus clearly on one point, but showed that pedestrians rather orient themselves at the curb than at the lane.

The thesis ends with recommendations about how future guidelines about curb extensions could look like.

## Kurzfassung

Gehsteigvorziehungen verbessern die Sichtbarkeit von querenden FußgängerInnen und Fahrzeugen auf Straßen mit Parkstreifen. Sie verkürzen die Querungslänge und bieten eine sichere Aufstellfläche für den Fußverkehr.

Im ersten Teil dieser Arbeit werden die nationalen Normen und Richtlinien aus Österreich, Deutschland und der Schweiz über Gehsteigvorziehungen an ungeregelten Kreuzungen verglichen.

Im zweiten Teil werden 100 bestehende Wiener Gehsteigvorziehungen überprüft, um herauszufinden, woran es liegt, wenn die erforderlichen Sichtweiten nicht erreicht werden; was 81 von 100 Mal der Fall war. Die meisten Gehsteigvorziehungen waren schmäler als der angrenzende Parkstreifen, oft wären die erforderlichen Sichtweiten bei Erweiterung der Gehsteigvorziehung bis zum Fahrbahnrand erreicht worden.

Im nächsten Schritt wurde mittels Videoanalyse FußgängerInnenverhalten analysiert, um die Ansätze in den Richtlinien für Gehsteigvoziehungen zu evaluieren. Die Anhaltepunkte von FußgängerInnen wurden erfasst und die Distanz zur Gehsteigkante und zur Fahrbahn gemessen. Die Verteilung der Anhaltepunkte war breit gestreut, es zeigte sich eine Tendenz zur Orientierung an der Gehsteigkante.

Zum Abschluss dieser Arbeit werden Empfehlungen ausgesprochen, wie zukünftige Richtlinien über Gehsteigvorziehunge aussehen könnten.

# Contents

# Chapter 1

# Definitions

This thesis discusses curb extensions at pedestrian crossings, which were installed to improve the visibility of cars and pedestrians and also reduce the crossing distance. Similar objects for speed reduction with no pedestrian crossing are not subject of this thesis.

## 1.1 Synonyms

The following terms have been found synonym for Curb Extension: bulbous kerb, bulb-out, choker, corner extension, kerb extension, neckdown and sidewalk expansion. In the German language there are different terms used in each country. In Austria it is called Gehsteigvorziehung, in Germany vorgezogener Seitenraum and in Switzerland Trottoirnase.

## 1.2 Pedestrian crossings

Pedestrian crossing can be regulated differently. This thesis defines three groups, of which two are going to be discussed. Signalised crossings are controlled by a traffic light or the police. They are not subject of this thesis. At Zebra crossings pedestrians have priority, approaching vehicles have to give way to pedestrians. The third group of crossings – regular crossings – contains all other crossings where pedestrians have to wait for a free gap to cross the street.

## 1.3 Layout

A curb extension can be looked at from two perspectives. The car driver sees it perpendicular to the pedestrian's view. The result is that length and width of the curb extensions can be interpreted in two ways. This thesis always uses the car drivers perspective, length and width of curb extensions are described as seen in figure 1.1:

The street is divided into lanes. The parking lane starts at the (not extended) curb. The next lane starts at the end of the parking lane, not at the end of the curb extension. Where the curb extension is wider than the parking lane, the lane starts right at the extended curb. At sites where the curb extension does not reach out to the parking lane, there is a space at the street, off the curb, which is not counted as lane.

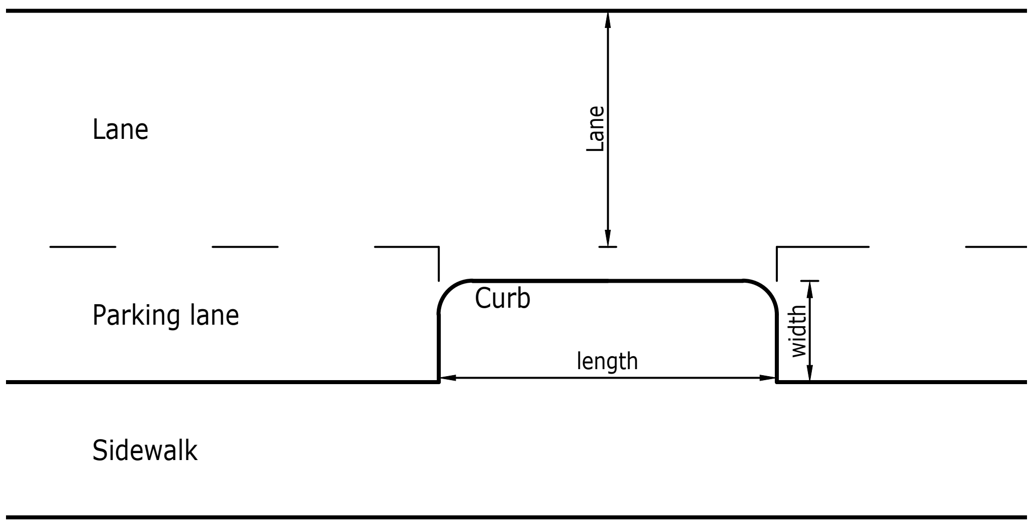


Figure 1.1: Layout Definitions

# Chapter 2

# Introduction

Walking is the basis of mobility. All trips – regardless of the mean of transport – start and end with a walk. The modal share of walking ranges widely in different countries and locations. In Austria 21% of all trips are walks (Schwab et al., 2012).

In most cities, pedestrians and vehicles are separated on the street. Pedestrians are expected to cross just at designated crosswalks, their walking lines are expected to be rectangular. Those crosswalks are built at locations with a high pedestrian crossing frequency.

The most popular locations of crosswalks are at intersections. But not all street crossing actions happen there. In fact, if there wasn't the barrier of cars in the middle of the streets, most crossings would not be rectangular at intersections, but diagonal and spread all over the street.

## 2.1 Objectives of curb extensions

Curb extensions provide additional space for pedestrians at streets with on-street parking. They enhance pedestrian safety by increasing the visibility and shortening the crossing distance. Well visible extensions raise the car drivers's attention to watch out for pedestrians.

At intersections, curb extensions slow down turning vehicles due to smaller turning radii. In addition, illegal parking at intersections is prohibited.

## 2.2 History

Streets used to be open for all means of transport and were a public space, where life took place. The first sidewalks were built in the Roman empire. They provided additional space for pedestrians, where they did not have to fear carriages or other vehicles and could walk above the street, which also functioned as drain those days. As it was additional, the sidewalk did not prohibit walking on the street.

It were also the Romans, who constructed the first known pedestrian crossings which connected both sidewalks of the street, see figure 2.1. Pedestrians could cross at the same level, without hindering carriages to pass, whose wheels those fit through the gaps between the stones (Olshausen and Sonnabend, 2002).

Figure 2.1: Pompeii, pedestrian crossing. By Berthold Werner,
CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=30440584

After the fall of the Roman empire, no sidewalks were built for a long time. It was after the great fire of London in 1666, when sidewalks came up again. Again, those sidewalks were optional for pedestrians, most people still walked on the street.

Such behaviour changed in the 20th century. In Switzerland, it was in 1932, when pedestrians were forced to walk on the sidewalks while vehicles could use the street. Designated locations were marked, where pedestrians should cross. (Schweizer, 2010)

The first zebra crossing was installed in England in 1949. Germany followed three years later. At those early crosswalks, pedestrians had no right of way. It took another decade until that changed. Since 1964, vehicles have to give way to pedestrians in Germany. (Geifes, 2012)

The first curb extensions were built in Europe in the 1970s. Leading countries were The Netherlands and Germany. In 1985, the city of Vienna implemented the first extensions – against the will of the local automobile clubs, but with the approval of the mayor. The reason for automobile clubs to fight against curb extensions was an alleged loss of parking space. However, they could be convinced that no legal parking space was lost, because it was prohibited to park a car closer than 5 meters to an intersection and curb extensions did not exceed this distance. Other Austrian cities followed Vienna's lead. Internal studies of Austrian traffic safety authorities showed a reduction of car vs. pedestrian and car vs. car accidents. Therefore the wish for more curb extensions arose quickly. Today, every new pedestrian crossing in Austria is designed with curb extensions; crossings with none are rebuilt subsequently. (Bernd Skoric, personal communication, October 28$^{th}$, 2015)

## 2.3 Types of curb extensions

Most curb extensions are short and facilitate pedestrians to cross at a designated route. Those locations are mainly at intersections.

The other type of curb extensions are longer ones, where pedestrians are not following a specific walking line, but cross all over a bigger crossing area. Those sites are found on shopping streets or in front of buildings with high pedestrian traffic.

There are several different types of curb extensions. Some reach out further than the parking lane (fig. 2.2). The Viennese standard curb extension is 20 cm shorter (fig. 2.3). Even smaller extensions can be found, possibly results of a change of the parking order from parallel to diagonal parking (fig. 2.4).

To improve visibility, a free space (e.g. green area or bicycle parking) is often provided next to the curb extension (fig. 2.5). Whereas bicycle parking on the curb leads to a reduced visibility (fig. 2.6).

At intersections or other locations with a bundled crossing need, curb extensions do not have to be long. Sometimes, mainly at mid-block extensions at shopping streets, no distinct pedestrian crossing route is used. In this case, long mid-block curb extensions make sense (fig. 2.7).

Other solutions found to create a rather secure space for pedestrians were a probably temporary solution (fig. 2.8) or road markings (fig. 2.9).


Figure 2.2: Wide curb extension
Engerthstraße / Hillerstraße, 1020 Wien

Figure 2.3: Typical Viennese curb extension
Goldschlagstraße / Hackengasse, 1150 Wien

Figure 2.4: Small curb extension
Steinbauergasse / Siebertgasse, 1120 Wien

Figure 2.5: Bicycle parking beside curb extension
Markus Sittikus-Straße / Faberstraße, 5020 Salzburg


Figure 2.6: Bicycle parking on the curb extension
Gumpendorfer Straße / Millergasse, 1060 Wien


Figure 2.7: Long mid-block curb extension
Hütteldorfer Straße / Hickelgasse, 1140 Wien


Figure 2.8: Temporary curb extension
Hietzinger Hauptstraße / Braunschweiggasse, 1130 Wien


Figure 2.9: Road markings instead of curb extension
Humboldstraße / Faberstraße, 5020 Salzburg

## 2.4 Research question and method

The fast triumph of curb extensions led to the creation of many sites with little scientific background. Regulations developed to ensure standards of visibility. Over the years, the planner's perspective switched from the car driver's perspective to a multi-modal view giving pedestrians' needs more weight. The current regulations demand more pedestrian friendly facilities than they did in the past.

But where do we stand in this process? Are the current regulations in Austria, Germany and Switzerland scientifically approved? Are newly built curb extensions really providing the required visibility ranges? What can be improved to ensure a safe environment at pedestrian crossings?

This thesis only covers curb extensions on non signalized crossings: zebra- and regular crossings. It starts with a literature analysis of scientific research about pedestrian crossings in general and curb extensions in particular.

The next part takes a close look at the national guidelines of Austria, Germany and Switzerland to show the details of curb extension design. After that, a field study is made which analyses existing curb extensions and pedestrian behaviour at crossings. The thesis ends with recommendations for guidelines about curb extensions.

# Chapter 3

# Literature review

## 3.1 Pedestrian behaviour

**Hamed (2001)** analysed pedestrian behaviour at zebra crossings. Waiting time and number of attempts to cross the street were recorded.

The most significant factors which influenced the pedestrian's waiting time and the frequency of attempts to cross the streets were: gender, age, number of children in household, crossing frequency, number of people in the group attempting to cross, access to private vehicle, destination, home location in relation to pedestrian crossing, and pedestrian past involvement in traffic accidents.

In addition it seemed, that the pedestrian's expected waiting time influenced the number of attempts needed to successfully cross the street.

**Johnson (2005)** did a case study in Albany, Oregon, USA about crosswalks, of which some had curb extensions.

It was found that at crosswalks with curb extensions pedestrians significantly had to let fewer vehicles pass before they could cross. An explanation for this is given by the improved visibility of approaching and waiting pedestrians. Pedestrian behaviour was observed and described as varying between passive and aggressive. Passive pedestrians stood back from the curb and waited for a vehicle to yield, while aggressive people stepped off the curb trying to get the vehicles to stop.

During heavy traffic, more pedestrians used the crosswalk while during non-peak hours, many crossed wherever convenient.

At pedestrian crossings without curb extensions the observed main waiting position was one step out from the curb. At curb extensions this behaviour was eliminated.

**Oxley et al. (2005)** examined age differences in gap selection decisions in a simulated road-crossing environment. Three groups of participants were tested: younger

(30–45 years), young–old (60–69 years) and old–old (>75 years).

The results showed that, for all age groups, gap selection was primarily based on vehicle distance. The younger and the young-old pedestrians judged the distance and speed of approaching vehicles correctly. The old-olds appeared to select insufficiently large gaps which led to a higher crash risk.

**Schweizer et al. (2009)** observed pedestrians and car drivers at zebra crossings.

Children were observed as very cautious, even if they were running across the street pretty often, because they did not run without coming to a stop beforehand. Old and handicapped pedestrians weren't observed to behave with more caution than others.

Stopping frequencies were the same for adults, children and elderly. Car drivers stopped more often only for handicapped pedestrians. The stopping frequency increased by the number of waiting pedestrians. When one car did not stop for a waiting pedestrian, it was more likely that succeeding cars would also rush through.

Additionally a standardised behaving pedestrian was set at a spot with exactly 50 m sight distance. Fewer cars stopped for him than for other persons with better visibility. This leads to the conclusion that most interactions between pedestrian and car driver begin more than 50 m away from the crossing.

**Sisiopiku and Akin (2003)** observed pedestrian behaviours at various urban crosswalks at pedestrian facilities in a divided urban boulevard in Michigan, USA.

It was evident that the crosswalk location, relative to the origin and destination of the pedestrian, was the most influential decision factor for pedestrians deciding to cross at a designated location.

**Turner et al. (2011)** did before and after studies in New Zealand where mid-block (in between junctions) curb extensions were built. They showed that only close walking lines moved their path to the new crossing facility while walking lines more than 30 m away from the crossing did not change. This shows how important it is to build pedestrian crossing facilities where they are needed and not where it is convenient.

**te Velde et al. (2005)** did a road crossing simulation. Adults, children aged 5-7 and children aged 10-12 had to cross a road safely before a vehicle arrived. Before and after the crossing the pedestrians were asked to judge when they could cross the road. Results indicated that

- the verbal judgement was not similar to the the actual behaviour;
- the younger the pedestrians, the longer they waited at the curb;

- all pedestrians increased their speed when it was unsafe.

## 3.2 Accident analysis

**Elvik and Vaa (2004)** estimated the general safety impact of curb extensions at about 5%.

**Johansson et al. (2004)** analysed police reports and behaviour studies about children and elderly as pedestrians and cyclists. More than 2.500 accidents were classified whether there were parked cars next to the crash site or not. It showed that next to parked cars accidents with children happened significantly more often than with adults. Johansson et al. therefore recommend curb extensions at pedestrian crossings next to parked cars.

**Land Transport Safety Authority New Zealand (1994)** analysed 60 sites where pedestrian refuge islands and/or curb extensions had been installed. Curb extensions only were built in 33 of the 60 cases. Sites with additional implementation of traffic signals or installation of street lightning were excluded.

The mean accident reduction at the sites was 23%, but in 14 of the 60 sites the number of accidents rose. Looking only at pedestrian accidents, the reduction was higher, namely 37% for intersections with new curb extensions. About the same impact was measured at sites with combined refuge islands and curb extensions.

## 3.3 Curb extension layout

There haven't been many studies dealing with the design of curb extensions published yet. Most of the studies look at the safety aspects of curb extensions while not considering the design of the curb extensions in detail. No studies were found dealing primarily with the exact design of curb extensions.

# Chapter 4

# Laws and regulations

Many countries have planning and design guides for pedestrians. This chapter will take a detailed look at the situation in Austria, Germany and Switzerland and compare it to other foreign examples.

## 4.1 Austria

The Austrian transport law *StVO 1960* regulates road traffic. The *Austrian Research Association for Roads, Railways and Transport (FSV)* published a code for the planning, construction and maintenance of roads and railways (RVS). The use of the RVS is recommended by the Austrian ministry for transport, innovation and technology, but not compulsory. Seven parts (of more than 300) mention curb extensions or closely related subjects. The main information is found in part 03.02.12 (pedestrian traffic).

### 4.1.1 Law

Pedestrian crossings with zebra markings give right of way to pedestrians when those are on the street or show the intent of crossing. Car drivers have to approach the crossing with a speed that they could stop when a pedestrian crosses the street. (§ 9) Pedestrians are not allowed to jump on the street surprisingly for the driver, even at zebra crossings. (§ 76) At regular crossings pedestrians are not allowed to put other people in danger. They have to wait for a free gap and cross the street swiftly.

Children have a different status: if a driver recognises a child (accompanied or unaccompanied) who wants to cross the street – regardless of road markings and signs – he has to stop and let them cross. (§ 29a)

### 4.1.2 RVS 02.02.32 Basics for authorised traffic experts

In this part of the RVS we find the most detailed information about curb extension design. It provides a list of purpose, advantages and disadvantages of several traffic calming elements.

The purpose of curb extensions is described as improvement of visibility, reduction of crossing distance and time. Advantages of increased road safety stand against loss of parking space. Curb extensions can be used in main and side streets of all widths, mainly with two lanes.

The recommended design is a 1,8 m wide extension on streets with car parking and 2,3 m wide extensions next to truck parking. Curb radii have to be rounded out correctly, the beginning of of the parking lane should be rounded out as well. Curb ramps shall be implemented for barrier-free access, bollards on the extensions are optional. The most common mistakes in the design of curb extensions mentioned are:

- short ranges of visibility
- wrong curb radii
- sight obstruction by traffic signs, plants, telephone boxes or waste containers

### 4.1.3 RVS 02.02.36 Barrier-free streets

In Austria, new infrastructure has to be barrier-free. This part of the RVS describes the correct construction of curb ramps, that on the one hand wheelchairs can pass but on the other hand blind people can feel the border between pavement and street. As a compromise it is recommended to build a 3 cm curb by either lowering the pavement or raising the lane. Usually two curb ramps should be provided at every corner, but at crossings with small curb radii there might be not enough space. In this case one ramp at the very corner is recommended.

### 4.1.4 RVS 03.02.12 Pedestrian traffic

Curb extensions can achieve the required sight distances at pedestrian crossings on streets with on-street parking. The curb is extended close (!) to the lane and creates a safe environment for waiting pedestrians. A free space between the end of the parking lane and the beginning of the waiting area depends on the necessary sight distances.

All objects obstructing the needed visibility range have to be removed to guarantee the visibility of pedestrians, especially for children. For this, it is necessary to keep all space between 0,6 m and 2,5 m height clear. At pedestrian crossings, it is differentiated between zebra- and regular crossings. The speed taken into calculation is not the maximum speed limit but the actually driven $v_{85}$.

**Zebra crossings**

The RVS regulates the construction of pedestrian crossings. In relation to pedestrian and car traffic volumes as well as other factors it is predefined which crossing type has to be implemented. To build a zebra crossing, the minimal number of pedestrians in the peak hour is 25. Below, no zebra crossing shall be installed. Figure 4.1 gives an overview about the process.

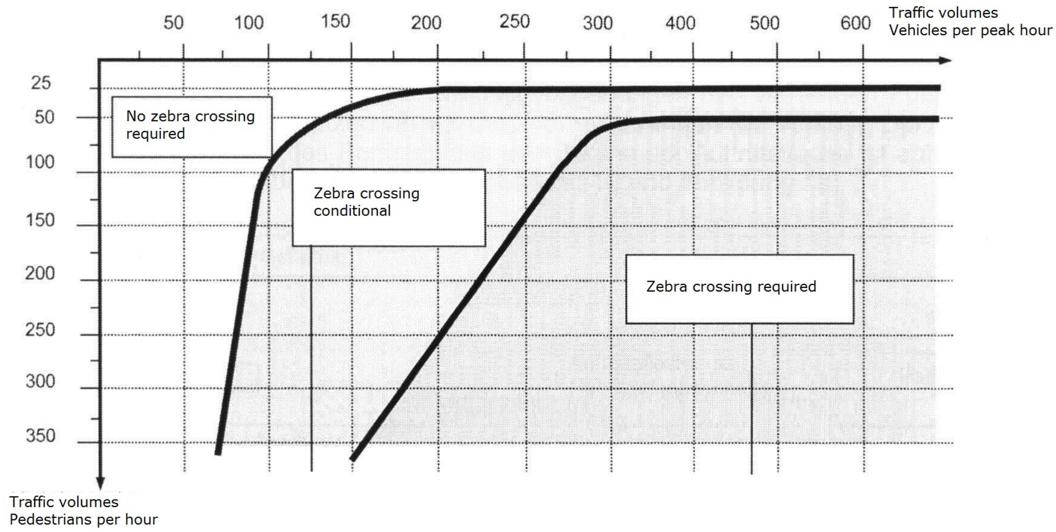


Figure 4.1: Criteria for the construction of zebra crossings

At zebra crossings the car driver has to recognise the approaching pedestrian and be able to stop in front of the markings. The point, where the pedestrian has to be seen is not right at the curb, but 1 m away from it. The curb extension lengths differ at the two sides. At the left side, where the car on the close line approaches, at least 3 m have to be kept free between the parking lane and the waiting area. At the right side it is just 1 m.

Figure 4.2 shows the design of curb extensions on zebra crossings. It can be seen that the line of sight goes through bicycle parking on the street at the bottom and through the parking lane at the top. As the vertical vision range goes from 0,6 to 2,5 m this could prove problematic.

A second point that has to be discussed is the position of the stopping distance ("l" in fig. 4.2). The dimensioning starts at the car driver and not the front end of the car, because the driver has to recognise the pedestrian. The end of the stopping distance dimensioning is directly at the crossing. This means, that when the car comes to a stop after the defined stopping distance, the driver will be at the before mentioned point and the bonnet will reach into the marked crosswalk.

Another undefined point is the position of the vehicle and the driver at the lane. Is he driving rather in the middle of the street or closer to the parking vehicles? The worst case (for visibility) would be a motorbike driving close to the parking lane. This definition is necessary to set the visibility ranges. Due to the acute angle in the vision triangle small changes of the car's (and driver's) position lead to huge differences in the resulting sight distance. The RVS doesn't give an answer to this question and makes it impossible to apply the demanded measures.

The position of the waiting pedestrian is set at the middle of the markings. This implies that pedestrians crossing at the edge of the markings might not be seen early enough.

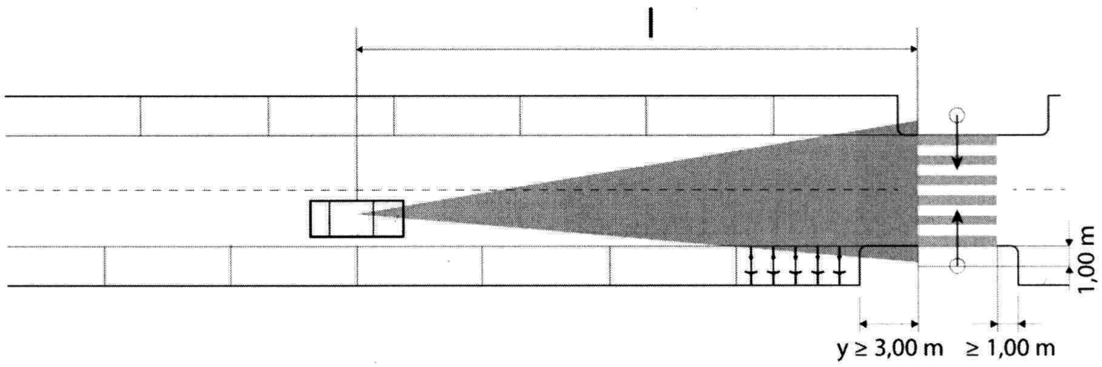


Figure 4.2: Visibility ranges on zebra crossings

The driven speed $v_{85}$ defines the length of the stopping distance. The vehicle deceleration is assumed as 3,5 to 4,5 $m/s^2$; the reaction time is set at 1,2 $s$. For selected speeds the necessary visibility ranges can be seen in table 4.1.

Table 4.1: Visibility ranges depending on speed at zebra crossings

| Speed $v_{85}$ [km/h] | 20 | 30 | 40 | 50 | 55 |
|---|---|---|---|---|---|
| Length l [m] | 10 | 20 | 30 | 45 | 52 |

**Regular crossings**

The pedestrians have to wait for a time gap to cross the street safely. So it is not the driver seeing the pedestrian but the other way round, the pedestrian seeing the car.

Other than at zebra crossings, the pedestrian is standing just 20 cm away from the curb to decide if it is possible to cross the street safely. Minimum length of curb extensions at regular crossings is 5,5 m, see fig. 4.3. Same as at zebra crossings, the necessary visibility just has to be fulfilled in the middle of the crossing and not across the whole width.

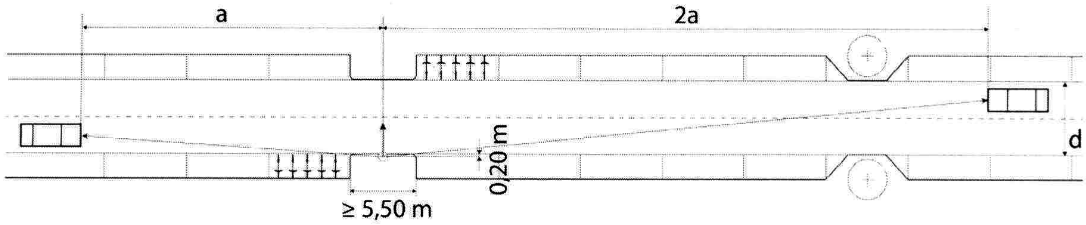


Figure 4.3: Visibility ranges on crossings without zebra markings

The sight required to guarantee a safe crossing depends on pedestrian speed (1,0 $m/s$), street width and approaching speed of the vehicles. Furthermore it is assumed that the car driver decelerates about 1,0 $m/s^2$ when a pedestrian is crossing the street in front of the car. On streets with two way service the required length of sight for the first lane (coming from left) is just half of the one for the second lane because of the shorter crossing distance. If there is a pedestrian island, the reduced distance can be applied for both lanes. This procedure to divide the distance by two is mathematically incorrect. When taking a look at the proposed formula 4.1 it can be seen that the crossing distance is contained twice. Once it goes into the calculation by the square. This means, that a division of the result by two does not bring the same results as the division of the crossing width by two. The result of a crossing width of 6 m is not double the result of a crossing width of 3 m.

$$2a = \frac{v_{85}}{3{,}6} * \frac{crossing\ dist.}{walking\ sp.} - \frac{car\ decel.}{2} * \left(\frac{crossing\ dist.}{walking\ sp.}\right)^2 \tag{4.1}$$

The 20 cm extra crossing distance from the waiting point to the curb is not included in the calculation of the necessary vision range. Same as for zebra crossings, the positions of the car at the lane and the pedestrian at the extension are not defined.

#### Undefined parameters

With the definitions and assumptions stated in the RVS it is not possible to calculate the necessary sight distance. Some further assumptions have to be made.

**Position of the car and the driver** As seen in fig 4.2 and fig. 4.3 the position of the car and the driver within the lane is not defined.

Practitioners use the middle of the lane for both the pedestrian recognising the car and the driver seeing the pedestrian. This assumption is also used in this thesis.

**Position of waiting pedestrians** All figures about curb extensions show mid-block extensions. But in reality, the biggest amount of curb extensions is located at intersections. There doesn't exist a definition, where the pedestrian is expected to cross at corner extensions as, they are not symmetric. At crossings with small curb radii where curb ramps don't fit at both sides of the corner, just one ramp is prescribed at the very corner, see section 4.1.3. It can be assumed that handicapped people will use the ramp, but fit ones will mainly use the direct path with a step off the curb.

For all this topics no definitions are found in the RVS. In this study the pedestrian walking path is set as the continuation of the middle of the pavement.

**Sight limiting objects** In Austria, parking spaces are not marked separately, it is just a dashed line running parallel to the street, or no line at all. Cars do not have to park exactly inside the marked area, they are not fined when the car overlaps the markings (even with a tyre), as long as the car is parked as close to the curb as possible and no other vehicle is hindered to pass, see StVO (1960) § 23. In the RVS on the one hand cars (or parking spaces) are regarded as sight obstruction, but in fig. 4.2 the sight axis goes through a parking lane. Further it is not defined, which width of vertical objects as traffic or light posts, trees, etc. is regarded as safe or not safe.

In this thesis the markings of the parking lanes are used to define the obstructed area.

**Car deceleration** The provided car decelerations range from 3,5–4,5 $m/s^2$. A single number would clarify the process and lead to comparable results.

**Imprecise graphics** Another definition lacking precision can be found in figures 4.2 and 4.3. The shown curb extensions all reach out right to the end of the parking lane. As a result is not clear, if the position of the waiting pedestrian has to be measured from the curb or from the lane, if curb extension and parking lane are not of the same width. The same goes with the crossing width at regular crossings. Should small curb extensions result in a bigger crossing width or not?

### 4.1.5 RVS 03.04.12 Cross section design of streets in built-up areas

Depending on the street hierarchy and the local speed limit, the RVS provides guidelines for pedestrian and bicycle crossings. Streets with a maximum speed limit of more than 50 km/h or more than 2 lanes have to separate the traffic flows by time (traffic light) or location (tunnel/bridge). For streets with 31 to 50 km/h, crossing aids like islands, curb extensions, etc. are recommended. In streets with 30 km/h or lower, it is recommended to install no crossing aids at all.

Standard widths of parking lanes are also defined in this part of the RVS. For parallel parking it is set at 2,0 m for cars and 2,5 to 3,0 m for trucks. Other measures for diagonal parking can be seen in figure 4.2.

Table 4.2: Parking lane widths, RVS 03.04.12

| | Angle | Parking lane width [m] |
|---|---|---|
| parallel parking cars | - | 2,0 (1,8)* |
| trucks | - | 2,5 - 3,0 |
| diagonal parking | 45° | 4,3 |
| | 60° | 4,6 |
| rectangular parking | 90° | 4,3 |

* for constricted rooms

### 4.1.6 RVS 03.04.14 School environment design

In this part of the RVS different measures for raising children safety around schools are rated in three categories: improvement of visibility, speed reduction, reduction of motorised traffic volumes. The scale ranges from 0 (no effect) to 4 (very good effects). Curb extensions are rated as follows:

- Improvement of visibility: 3 (good effects)
- Speed reduction: 1 (little effects)
- Reduction of motorised traffic volumes: 0 (no effect)

It is mentioned that better results can be achieved in combination with parking restrictions. At sites with parking at the street, there are twice as many accidents with children than in parking restricted areas.

### 4.1.7 Additional guidelines

The City of Vienna published an official planning manual, which states, that curb extensions are state of the art and should be implemented at all new intersections. The sight distances have to comply with the RVS (Nuß and Nestler, 2011).

The municipal department for road management and construction (MA 28) designs curb extensions with a width of 20 cm less than the street markings for parking. For example a parallel parking lane width of 2,0 m leads to a curb extension length of 1,8 m. This design has been used over the years, but cannot be found in any regulations or guidelines.

The justification of the 20 cm difference is the reduced risk of damaging tyres when a car accidentally runs over the curb.

Curb radii at intersections are defined by turning curves of design vehicles. Those design vehicles are either vehicles for refuse collection or public transport.

## 4.2 Germany

In Germany there are two documents dealing with curb extensions. The *EFA* looks at pedestrian facilities and the *RASt* covers urban streets.

### 4.2.1 EFA Recommendations for pedestrian facilities

In EFA (Empfehlungen für Fußgängerverkehrsanlagen) curb extensions (*vorgezogene Seitenräume*) should always reach out further than the parking lane width, the recommended range is from 30 to 70 cm. Over 70 cm, the risk of cars parking diagonally instead of parallel to the lane reduces the positive effects of extensions. With rectangular or diagonal parking it is possible to increase the extension width to 1,2 m in front of the parking lane. At streets with bicycle lanes it is not permitted to build curb extensions.

To guarantee good visibility there are two different measures: the visual range and the length of free space in front of the crossing. It is differentiated between left and right, as the cars coming from left are driving right next to the curb and the cars approaching from right have the other lane in between.

The position of the waiting pedestrian is not defined, but at regular crossings the symbol is drawn closer to the curb than at zebra crossings, see fig. 4.4. The pedestrian is assumed to wait exactly in the middle of the crossing. Sight does not have to comply with the rules for pedestrians waiting at the edge of the crossing. The exact position of the car or the driver is not defined. Although it is said that parking vehicles are prohibiting sight, the line of sight shown in *EFA* goes directly through an (unoccupied) parking place. The requested visual ranges can be seen in table 4.3

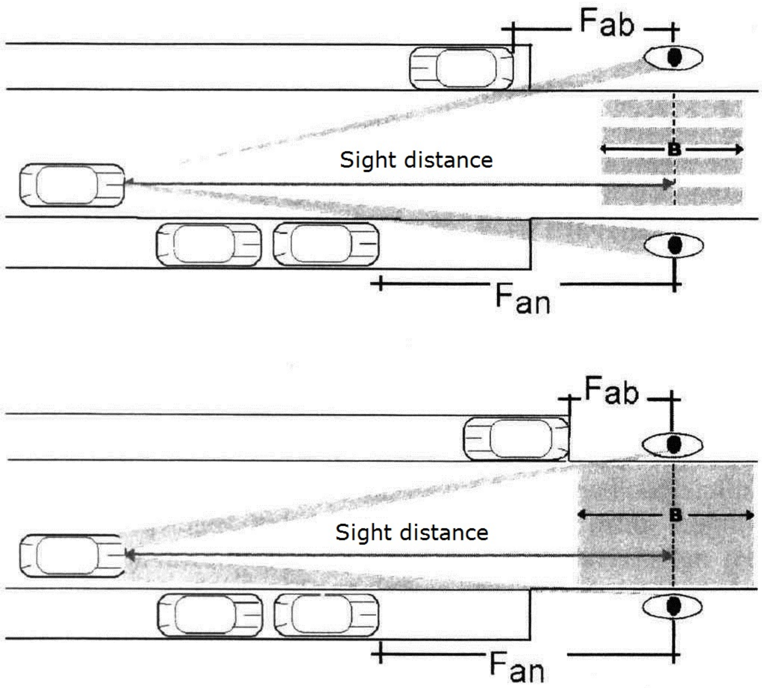


Figure 4.4: Vision ranges in the German EFA

Table 4.3: Visual ranges by speed and direction in the German EFA

| **Vehicle Speed [km/h]** | | **30** | **40** | **50** |
|---|---|---|---|---|
| Visual range [m] | | 30 | 35 | 50 |
| Stopping visual range [m] | | 15 | 25 | 35 |
| Free space sideways without curb extensions [m] | L | 10 | 15 | 20 |
| | R | 5 | 10 | 15 |
| Free space sideways with curb extensions [m] | L | 5 | 8 | 12 |
| | R | 3 | 4 | 6 |
| | | Minimum width: $\geq B/2$ | | |

### 4.2.2 RASt Guidelines for city streets

The second paper regulating curb extensions in Germany is the *RASt* (Richtlinien für die Anlage von Stadtstraßen). Some of the rules are the same as in *EFA*, but there are differences as well. In *RASt* there are no vision ranges defined, just the necessary free spaces next to the pedestrian crossing. This definition is more precise than in *EFA*.

One point which only appears in *RASt* is, that pedestrians at zebra crossings have to be recognised standing 1 m away from the curb. At regular crossings, it is written, that pedestrians are "orienting themselves rather directly at the curb", so the same distances can be applied at regular crossings as for zebra crossings.

## 4.3 Switzerland

### 4.3.1 SN 260 212 Street design elements

Curb extensions are listed in chapter 10.2 as *vorgezogene Seitenräume*. They are described as periodic gaps in parallel parking lanes without narrowing the driving lanes. Aims are to ...

- facilitate the crossing of streets for pedestrians and cyclists
- enhance visibility between drivers and pedestrians or cyclists
- provide waiting areas
- reduce optical dominance of wide lanes
- "chamber" the road space

Figure 4.5 shows a typical Swiss curb extension. The length of curb extensions should be determined after the request of the waiting area. A minimum of 4 m should be provided at all sites. In situations were the visibility needs to be improved, it is possible to extend the curb to a maximum of 20 cm further than the parking lane. In this case, the curb must be clearly visible, especially for cyclists. For "chambering" the road space, it is recommended to combine curb extensions with planted trees. Curb extensions should be equipped with vertical elements to prohibit vehicles from parking there.

### 4.3.2 SN 640 241 Zebra Crossings

Zebra crossings are regulated in a special Swiss norm. The required sight distances have to be kept free from 0,6 to 2,5 m height. Depending on the driven speed $v_{85}$ the

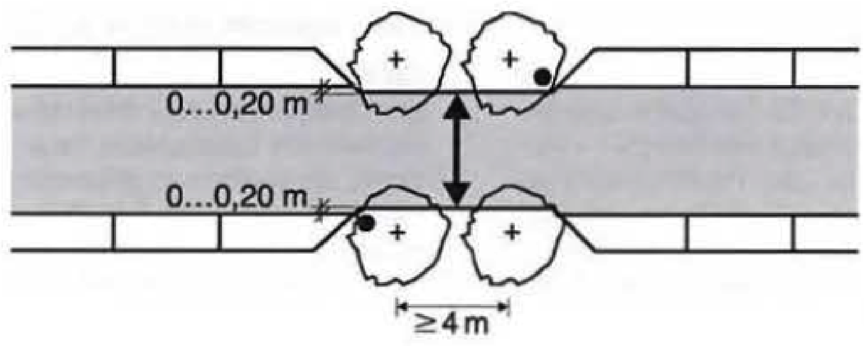


Figure 4.5: Swiss example of a curb extension

sight distances can be seen in table 4.4. Where the $v_{85}$ is lower than the speed limit, the speed limit or the $v_{85}$ can be taken. If the $v_{85}$ is higher than the speed limit, only the $v_{85}$ is allowed to be taken into the calculation.

Table 4.4: Necessary sight distances at zebra crossings, SN 640 241

| Speed $v_{85}$ [km/h] | 30 | 40 | 50 | 60* | 60** |
|---|---|---|---|---|---|
| Sight distance [m] | 25 | 40 | 55 | 75 | 100 |

* Inside built-up area

** Outside built-up area

The waiting area, which has to be seen completely, starts 1 m behind and 1 m beside the crossing, see figure 4.6. The visibility range should be kept free of all objects. Exceptions can be made for light poles with a diameter of max. 20 cm. The position of the driver is assumed to be in the middle of the lane.

In bends, other sight distances apply, but still the same waiting area exists, which has to be overlooked completely by the car driver. An example of a zebra crossing with curb extensions can be seen in figure 4.7. The extension at the top is as wide as the parking lane, the one at the bottom is wider.

In this figure the size of the waiting area is not true to scale. It has one third of the parking lane's width which leads to a 3 m wide parallel parking lane. With a correctly drawn waiting area the curb extension had to be longer.

### 4.3.3 SN 640 213 Traffic calming elements

Depending on the speed limit and the hierarchy of the street, minimal sight distances at traffic calming elements are defined. The required sight distances are the same

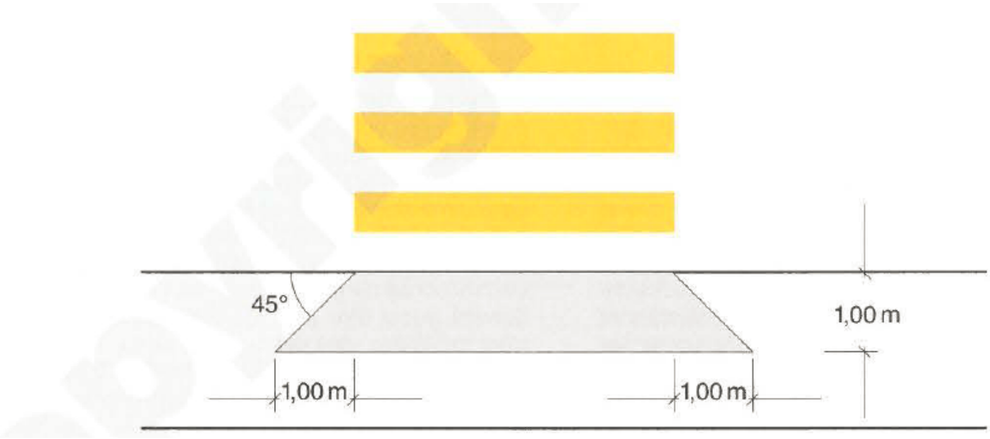


Figure 4.6: Waiting area, SN 640 241

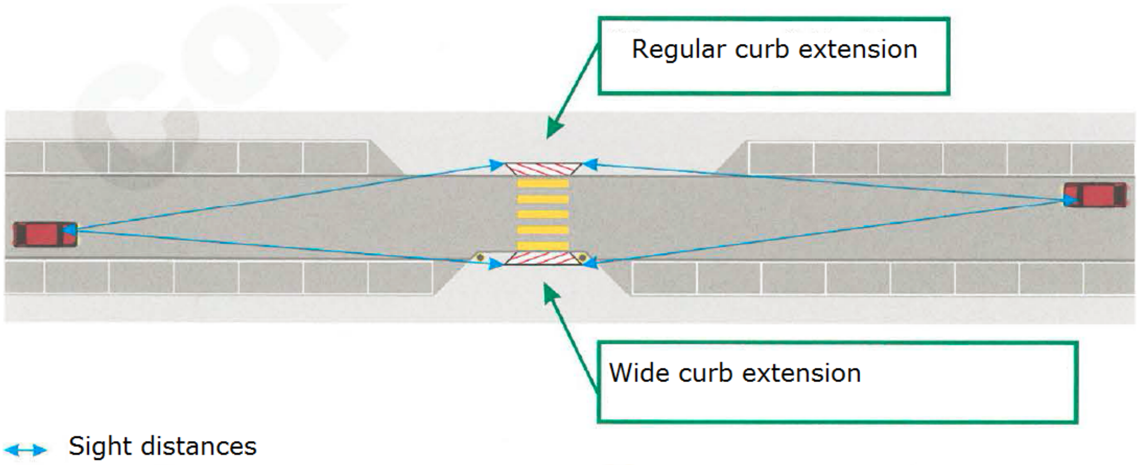


Figure 4.7: Example of a Swiss curb extension, SN 640 241

or shorter than those required at zebra crossings, see table 4.5.

Table 4.5: Necessary sight distances at traffic calming elements (SN 640 213)

| Street type | collecting road | | local streets | | |
|---|---|---|---|---|---|
| Speed limit [km/h] | 50 | 30/40 | 50 | 30/40 | 20 |
| Sight distance [m] | $\geq 35$ | $\geq 25$ | | | $\geq 15$ |

## 4.4 Comparison

The three presented regulations show different approaches on how to design curb extensions. In all countries there are at some point different requirements for zebra- and regular crossings. Germany always takes the official speed limit for the definition of visibility, Austria and Switzerland use the driven speed $v_{85}$.

One thing that is missing in all three countries is the subject of curb extensions at intersections. In all countries there are way more curb extensions located at intersections, mid-block extensions are rarely found.

However, all guidelines just show curb extensions at streets with no intersection. It is possible to design curb extensions at intersections with the guidelines, but all problems coming up only at intersections are not touched. For example there are no rules or proposals given how to deal with the conflict of providing turning radii for large vehicles versus building the curb extension at the same width of the parking lane. The layout analysis will show that 40% of recorded extensions had an offset due to turning radii.

### 4.4.1 Zebra crossings

At zebra crossings all countries see the waiting pedestrian 1,0 m away from the curb, but nobody gives an explanation what led to this measure. In Switzerland, the waiting pedestrian is assigned to a waiting area which is clearly defined. In Austria and Germany, the pedestrian is put into the middle of the crossing.

The Swiss norm is the only one of the three countries that defines the position of the driver within the lane. In Austria and Germany this definition is missing and therefore the sight distances can not be determined. Additionally the German EFA has another definition to ensure visibility by defining a space that has to be kept clear beside the extension.

Every country has different sight distances. For example at zebra crossings with a driven car speed and speed limit of 50 km/h the necessary distances are in Germany 15 m, in Austrian 20 m and in Switzerland 25 m. The Austrian RVS is the only regulation which delivers insight into its calculations with reaction time and car deceleration.

A summary of the comparison of the different regulations can be seen in table 4.6. The therein used measures are defined in figure 4.8.

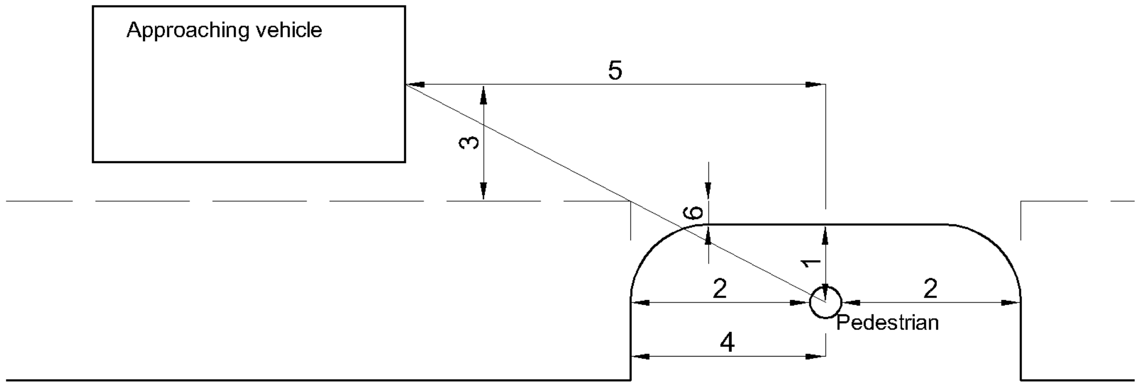


Figure 4.8: Measures for table 4.6 and 4.7

### 4.4.2 Regular crossings

At regular crossings the Austrian RVS is the only regulation which provides a precise measure where the waiting pedestrian is expected to be located, namely 20 cm away from the curb. In Germany the pedestrian "orients himself rather directly at the curb" and in Switzerland the same distance as at zebra crossings – 1 m – is used.

For the calculation of the sight distances it is again the Austrian RVS that provides physical measures and a formula to calculate the distance. Switzerland does not provide formulas, but demands the use of the driven speed $v_{85}$. To get the necessary distances, it has to be interpolated. The Swiss norm does not define the method of interpolation between two sight distances. The most common one, the linear interpolation, will lead to results lower than they should be, as the distance increases by the square of the speed. In Germany those problems do not appear, as only the official speed limit has to be used and for those speeds there is no need of interpolating.

Austria is the only country that includes the width of the street into the definition of sight distances on regular crossings. It is also the only country that allows to cut the sight distance in half for the left side as cars can pass when the pedestrian is still on the street but on the other lane.

A summary of the comparison of the different regulations can be seen in table 4.7.

Table 4.6: Comparison of different national guidelines, zebra crossings. Definitions of measures can be seen in figure 4.8

| **Nr** | | **Unit** | **Austria** | **Germany** | **Switzerland** |
|---|---|---|---|---|---|
| 1 | Position of waiting pedestrian | m | 1,0 | 1,0 | 1,0 |
| 2 | | | Middle of crossing | middle of crossing | Defined Waiting area |
| 3 | Position of driver | m | not defined | not defined | middle of lane |
| 4 | Minimum length with no parking | m | 3 | 5/8/12* | not defined |
| 5 | Sight distance | | | | |
| | 30 km/h | m | 20 | 15 | 25 |
| | 40 km/h | m | 30 | 25 | 40 |
| | 50 km/h | m | 45 | 35 | 55 |
| | Vertical vision range | m | 0,6 - 2,5 | not defined | 0,6 - 2,5 |
| 6 | Curb extension width | | 20 cm less than width of parking lane | 30 ... 70 cm more than parking lane | 0 ... 20 cm more than parking lane |

* for 30/40/50 km/h. If the extension reaches out more than 30 cm in front of the parking lane, 5 m can be applied at all speeds

Table 4.7: Comparison of different national guidelines, regular crossings

| Nr | | Unit | Austria | Germany | Switzerland |
|---|---|---|---|---|---|
| 1 | Position of waiting pedestrian | m | 0,2 | close to the curb | 1 |
| 2 | | | middle of crossing | middle of crossing | Width of markings |
| 3 | Position of car | m | not defined | not defined | middle of lane |
| 4 | Minimum length with no parking | m | 5,5 | 5/8/12* | |
| 5 | Sight distance | | | | |
| | 30 km/h | m | 25/50** | 30 | 25 |
| | 40 km/h | m | 34/68** | 35 | 25 |
| | 50 km/h | m | 43/86** | 50 | 25/35*** |
| | Vertical vision range | m | 0,6 – 2,5 | not defined | 0,6 – 2,5 |
| 4 | Curb extension width | | 20 cm less than width of parking lane | 30 ... 70 cm more than parking lane | 0 ... 20 cm more than parking lane |

* for 30/40/50 km/h. If the extension reaches out more than 30 cm in front of the parking lane, half of the marked crossing width is enough

** Left/right for a 6,5 m street width

*** Local streets/collecting streets

### 4.4.3 Curb extension width

An aspect that will play a big part in the layout analysis is the width of the curb extensions. In principle, the necessary sight distances can be achieved with all widths, even where no curb extensions at all exist. It just takes very large areas that have to be kept free of sight limiting objects beside the extension.

The recommendations regarding curb extensions' width of the three countries differ widely. In Austria, a curb extension should not reach out to the lane, it should end 20 cm before. In Switzerland, it should be either of the same width of the parking lane or 20 cm wider. And in Germany, it ranges from 30 cm wider to 70 cm wider than the parking lane.

### 4.4.4 Sight distances

This study does not judge whether the assumed measures of lengths, speeds and decelerations are realistic or not. What is discussed here is if the methods used in the guidelines have systematic errors that lead to short sight distances.

Austria provides physical formulas and measures to calculate the sight distances. This enables to exactly calculate the required sight distances for all speeds without interpolation.

Switzerland does not provide those formulas. They just present tables where the sight distances can be read off for specific speeds. If you need the necessary sight distance for a speed that is not presented in the norm, you have to interpolate. If you interpolate linearly, you will get short distances. As the braking distance grows with the square of the speed, there will be a standard error at the unsafe side.

In Germany, the driven speeds do not go into calculation at all. Without any proof that in Germany speed limits are complied with all the time, this method will lead to short sight distances.

## 4.5 Foreign examples

Besides the three German speaking countries other guidelines were checked. Interesting approaches not mentioned in the three countries' rules are presented in this section.

### 4.5.1 San Francisco

A planning handbook from San Francisco was published, which builds up on the *National Complete Streets Coalition*. The *San Francisco Better Streets plan* seeks safe transport for all modes and an increased livability of public space and better

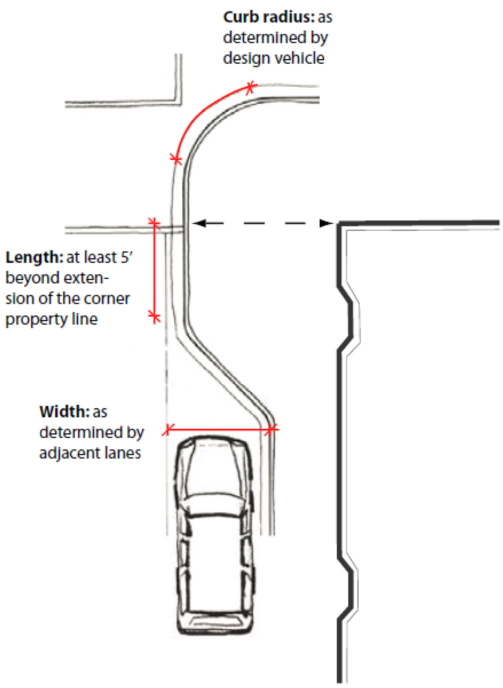


Figure 4.9: Typical dimensions of curb extensions, SFPD (2010)

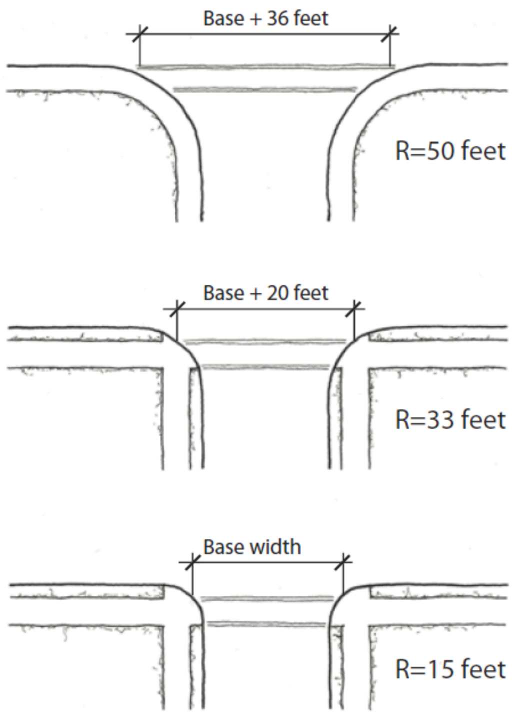


Figure 4.10: Small curb radii reduce crossing distance, SFPD (2010)

stormwater treatment. It recommends curb extensions among others on new streets and on streets with high pedestrian volumes and/or high traffic volumes and speeds.

> Bulb-outs should be designed to maximize pedestrian space and minimize crossing distances as much as feasible, while allowing vehicle movements. The width should be maximized based on space for adjacent vehicle and bicycle travel lanes. The bulb-out should extend to the full width of the parking lane.

Other that the European examples, this manual deals with curb extensions at intersections. Turning radii are discussed widely. It is stated that the turning radius should be determined by a design vehicle (see figure 4.9), but the negative impacts of large turning radii are shown to increase the sensibility of planners on that subject (figure 4.10). (San Francisco Planning Department, 2010)

Another approach is presented for intersections with too little space for curb extensions at all four corners. In such a case it is recommended to install curb extensions at opposing corners to shorten each crosswalk a little, see figure 4.11.

The *San Francisco Better Streets Plan* offers an alternative solution for the design of curb extensions. Without changing the effective turning radius, the actual curb

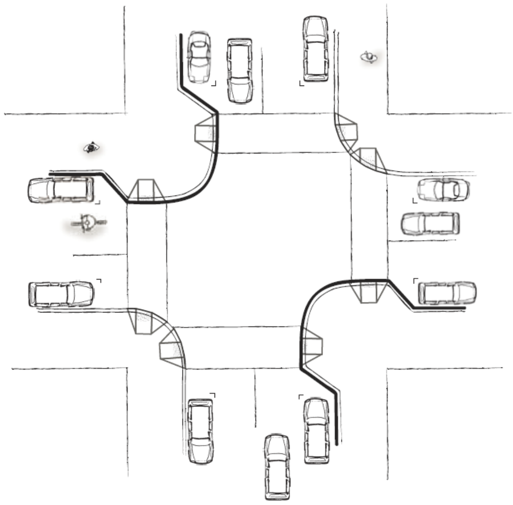

Figure 4.11: Extensions on opposite corners

radius can be decreased to create a clear directionality by reducing the extension's width, see figure 4.12. Both solutions are described as acceptable.

### 4.5.2 New Zealand

The New Zealand Transport Agency published a pedestrian planning and design guide which covers curb extensions. It claims to promote a "world's best practice" approach and supports the national transport strategy.

The handbook offers a detailed description of the design of curb extensions, not only the width and length but the curve radii at the end where the parking lane begins. This subject is not covered as detailed by the other presented guidelines. As can be seen in figure 4.13 there are two curve radii. One convex and one concave. No abrupt changes in the curb directions shall be made to enable mechanical street sweeping, which is possible above 5 m radii.

What is not mentioned in this picture is where the parking lane begins. The round curb provides no clear rules where it is still legal to park the car and where it is not. This would be clear with hard breaks in the direction of the curb.

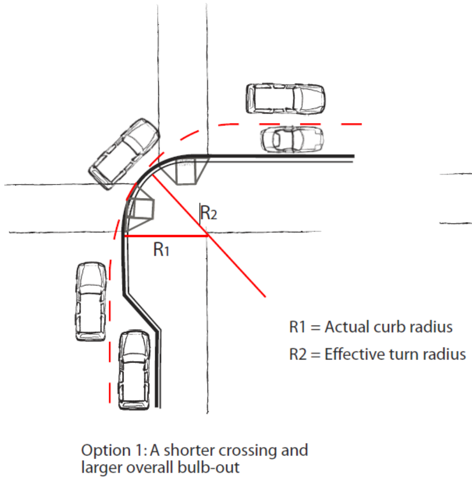


Figure 4.12: Alternative shapes of curb extensions, SFPD (2010)

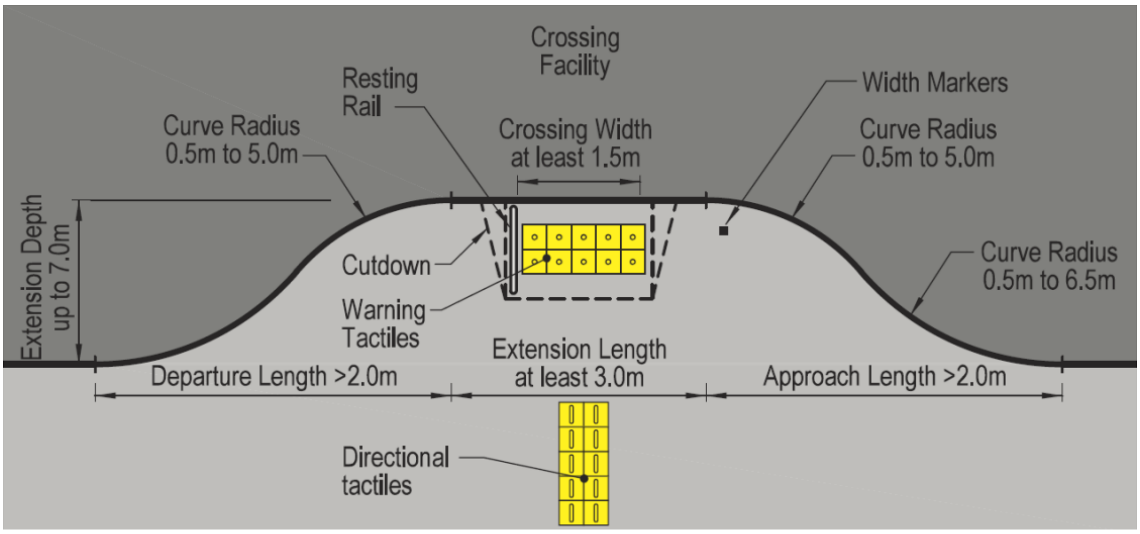


Figure 4.13: Dimensions of curb extensions, NZ Transport Agency (2009)

# Chapter 5

# Field study

## 5.1 Layout analysis

### 5.1.1 Method

#### Street Layout

At every examined curb extension the theoretical sight distances were registered. At the beginning, both directions of approaching vehicles were included in the survey. After 50 recordings a first evaluation of the process was made. It showed that not a single of the 50 curb extensions had insufficient visibility at the side facing the intersection. It was only the far side that sometimes failed to provide the necessary sight distances.

Those findings led to the decision to look only at the far side of the extensions in future.

Not only the dimensions of the curb extensions were recorded, but the number and width of all lanes pedestrians had to cross. This was necessary to define the existing sight distances.

All dimensions in length and width were taken from official maps or measured directly at the site. The closest possible legal position of a sight limiting object (e.g. a parked car) was measured at a local inspection. In most cases, parking cars were the sight limiting objects. Where the parking lane was defined by markings, the outer edge was used as closest possible position. At sites without road markings the standard widths shown in table 4.2 were taken. Practitioners also use those definitions to define the sight distances.

After collecting all layout data of the curb extension, a walking line was defined to set the position of the waiting pedestrian. The walking line shows, where most pedestrians cross the street. Usually this line starts and ends at the centre of each crossing sidewalk. In some cases the walking line may be offset, when most pedestrians use another walking line (e.g. at bus stops).

#### Speed

The velocity of approaching vehicles is not the same as the local speed limit. The RVS explicitly mentions that the $v_{85}$ percentile has to be used. For this reason the speed of approaching cars was measured with a radar gun.

A minimum of 20 cars were recorded to get an adequate $v_{85}$ speed. In streets with low traffic volumes, speed was not measured at every analysed curb extension. Representative speed measures were taken and applied to streets where speed wasn't recorded.

#### Selection of sites

With one exception all analysed crossings were in Vienna. The attempt was to find differently shaped extensions to get an overview over all extensions existing. As in Vienna, curb extensions are paid for by the local district, there is an inhomogeneous allocation of curb extensions all over town. With this in mind, extensions in seven different districts were examined. The attempt was to find good and bad examples as well as special solutions.

What was not the aim of the layout analysis, is to give a precise number of (according to the RVS) good or bad curb extensions. It is no random sample, no statements about the collective can be made.

After the decision of just looking at the sight distances at the far side of the intersection, some extensions in one way streets dropped out of the list. The final list of analysed curb extensions contains 100 cases and can be seen in Table 5.1. The details of all sites are attached in Appendix A.

### 5.1.2 Calculation

With the complete layout and the walking line, the actual sight distances could be calculated. The waiting pedestrian was put at the spot where the RVS defines it: 1,0 m (zebra crossings) or 0,2 m (regular crossings) away from the curb.

The $v_{85}$ speed of the approaching cars defined the necessary sight distance to provide a safe crossing. The actual sight distance was compared with the necessary one and gave information whether the crossing complied with the local guidelines or not.

Table 5.1: List of recorded intersections

| Intersection nr. | Street 1 | Street 2 | Address | | Recorded extensions | Main road | residential road | Zebra | non zebra | behaviour analysed |
|---|---|---|---|---|---|---|---|---|---|---|
| 01 | Husterg. | Meiselstr. | 1140 | Vienna | 6 | | 6 | 6 | | |
| 02 | Hütteldorfer Str. | Hickelg. | 1140 | Vienna | 4 | 4 | | | 4 | 1 |
| 03 | Husterg. | Märzstr. | 1140 | Vienna | 5 | | 5 | | 5 | |
| 04 | Beckmanng. | Märzstr. | 1150 | Vienna | 8 | | 8 | | 8 | 1 |
| 05 | Flachg. | Märzstr. | 1150 | Vienna | 7 | | 7 | | 7 | |
| 06 | Flachg. | Meiselstr. | 1150 | Vienna | 8 | | 8 | | 8 | |
| 07 | Beckmanng. | Meiselstr. | 1150 | Vienna | 8 | | 8 | 8 | | |
| 08 | Reinlg. | Meiselstr. | 1140 | Vienna | 8 | 4 | 4 | | 8 | |
| 09 | Märzstr. | Reinlg. | 1140 | Vienna | 6 | | 6 | 2 | 4 | 1 |
| 10 | Thaliastr. | Wurlitzerg. | 1160 | Vienna | 1 | 1 | | | 1 | |
| 11 | Thaliastr. | Schuhmeierpl. | 1160 | Vienna | 2 | 2 | | | 2 | |
| 12 | Ottakringer Str. | Steinerg. | 1170 | Vienna | 6 | 4 | 2 | 2 | 4 | |
| 13 | Martinstr. | Antonig. | 1180 | Vienna | 4 | | 4 | 4 | | |
| 14 | Goldschlagg. | Stättermayerg. | 1150 | Vienna | 5 | | 5 | | 5 | |
| 15 | Penzinger Str. | Diesterwegg. | 1140 | Vienna | 2 | | 2 | 2 | | |
| 16 | Auhofstr. | St. Veit G. | 1130 | Vienna | 6 | | 6 | 6 | | |
| 17 | Hütteldorfer Str. | Mitisg. | 1140 | Vienna | 4 | 4 | | | 4 | |
| 18 | Schmalzhofg. | Stumperg. | 1060 | Vienna | 2 | | 2 | 2 | | 2 |
| 19 | Millerg. | Linieng. | 1060 | Vienna | 4 | | 4 | | 4 | |
| 20 | Reumannpl. | Ettenreichg. | 1100 | Vienna | 1 | 1 | | | 1 | 3 |
| 21 | Franz Josef Str. | Vierthalerstr. | 5020 | Salzburg | 2 | 2 | | 2 | | |
| 22 | Gumpendorferstr. | Gfrornerg. | 1060 | Vienna | 1 | | 1 | | 1 | |
| | | | | **Sum** | **100** | **22** | **78** | **34** | **66** | **8** |

For curb extensions that did not fulfil the demands an additional analysis was made. As most of the failing extensions did not reach to the lane it was calculated if the sight distance would have been big enough if the extension reached out right to the lane. If this still wasn't enough either the extension had to be wider than the parking lane or the sight limiting object had to be moved away from the crossing.

**Required sight distance (according to the RVS)**

$$s_{r,zebra} = \frac{v_c}{3{,}6} \cdot t_r + \left(\frac{v_c}{3{,}6}\right)^2 \cdot \frac{1}{2 \cdot d_s} \tag{5.1}$$

$$s_{r,regular} = \frac{v_c}{3{,}6} \cdot \frac{w}{v_p} - \left(\frac{w}{v_p}\right)^2 \cdot \frac{d_{ns}}{2} \tag{5.2}$$

| | |
|---|---|
| $s_r$ | required sight distance [m] |
| $d_{ns}$ | car deceleration, not stopping: 1,0 $m/s^2$ |
| $d_s$ | car deceleration, stopping: 4,5 $m/s^2$ |
| $t_r$ | car driver reaction time: 1,2 $s$ |
| $v_c$ | driven car speed $v_{85}$ [km/h] |
| $v_p$ | pedestrian walking speed: 1,0 $m/s$ |
| $w$ | crossing width [m] |

**Actual sight distance**

$$s_{a,zebra} = \frac{1{,}0 + x}{1{,}0 + \Delta} \cdot a \tag{5.3}$$

$$s_{a,regular} = \frac{0{,}2 + x}{0{,}2 + \Delta} \cdot a \tag{5.4}$$

| | |
|---|---|
| $s_a$ | actual sight distance [m] |
| $x$ | Distance curb – middle of the approaching lane (= where the driver is assumed to be) [m] |
| $\Delta$ | Distance curb – sight limiting object forward (positive values for bigger parking lanes) [m] |
| $a$ | Distance walking line – sight limiting object sideways [m] |

**Speed for safe crossing**

$$s_{r,zebra} = \frac{v_{85}}{3,6} \cdot t_r + \left(\frac{v_{85}}{3,6}\right)^2 \cdot \frac{1}{2 \cdot d_s} \tag{5.5}$$

$$s_{a,zebra} = \frac{v_{safe,zebra}}{3,6} \cdot t_r + \left(\frac{v_{safe,zebra}}{3,6}\right)^2 \cdot \frac{1}{2 \cdot d_s} \tag{5.6}$$

$$v_{safe,zebra} = 3,6 \cdot \left(\sqrt{d_s^2 \cdot t_r^2 + 2 \cdot d_s \cdot s_{a,zebra}} - d_s \cdot t_r\right) \tag{5.7}$$

$$v_{safe,zebra} = 3,6 \cdot \left(\sqrt{29,16 + 9 \cdot s_{a,zebra}} - 5,4\right) \tag{5.8}$$

$$s_{r,regular} = \frac{v_{85}}{3,6} \cdot \frac{w}{v_p} - \left(\frac{w}{v_p}\right)^2 \cdot \frac{d_{ns}}{2} \tag{5.9}$$

$$s_{a,regular} = \frac{v_{safe,regular}}{3,6} \cdot \frac{w}{v_p} - \left(\frac{w}{v_p}\right)^2 \cdot \frac{d_{ns}}{2} \tag{5.10}$$

$$v_{safe,regular} = 3,6 \cdot \left(\frac{d_{ns} \cdot w}{2 \cdot v_p} + \frac{v_p \cdot s_{r,regular}}{w}\right) \tag{5.11}$$

$$v_{safe,regular} = 3,6 \cdot \left(\frac{w}{2} + \frac{s_{a,regular}}{w}\right) \tag{5.12}$$

$d_{ns}$ car deceleration, not stopping: 1,0 $m/s^2$
$d_s$ car deceleration, stopping: 4,5 $m/s^2$
$s_a$ actual sight distance [m]
$s_r$ required sight distance [m]
$t_r$ car driver reaction time: 1,2 $s$
$v_{85}$ driven car speed [km/h]
$v_p$ pedestrian walking speed: 1,0 $m/s$
$v_{safe}$ speed for safe crossing [km/h]
$w$ crossing width [m]

### Sight distance if curb was extended to the lane

Where the curb extension does not reach to the lane, it was calculated if the necessary sight distance could be reached by extending the extension to the curb. This new distance was compared to the required sight distance to check if the situation could be rehabilitated with this action.

$$s_{cl,zebra} = \frac{(1{,}0 + x)}{1{,}0} \cdot a \tag{5.13}$$

$$s_{cl,regular} = \frac{(0{,}2 + x)}{0{,}2} \cdot a \tag{5.14}$$

| | |
|---|---|
| $s_{cl}$ | sight distance if the curb was extended to the lane [m] |
| $x$ | Distance curb – middle of the approaching lane (= where the driver is assumed to be) [m] |
| $a$ | Distance walking line – sight limiting object sideways [m] |

### Missing distance walking line – sight limiting object (SLO) sideways

It was calculated, how far the beginning of the parking lane (or other SLO) had to be moved to provide the demanded visibility without changing the width of the curb extension.

$$a_{m,zebra} = \frac{s_{r,zebra}}{1{,}0 + x} \cdot \left(1{,}0 + \Delta - \frac{(1{,}0 + x) \cdot a}{s_{r,zebra}}\right) \tag{5.15}$$

$$a_{m,regular} = \frac{s_{r,regular}}{0{,}2 + x} \cdot \left(0{,}2 + \Delta - \frac{(0{,}2 + x) \cdot a}{s_{r,regular}}\right) \tag{5.16}$$

| | |
|---|---|
| $a$ | actual distance walking line – sight limiting object sideways [m] |
| $a_m$ | missing distance walking line – sight limiting object sideways for a safe crossing [m] |
| $s_r$ | required sight distance [m] |
| $x$ | Distance curb – middle of the approaching lane (= where the driver is assumed to be) [m] |
| $\Delta$ | Distance curb – sight limiting object forward (positive values for bigger parking lanes) [m] |

**No offset, necessary SLO move**

$$a_{m,cl,zebra} = 1{,}0 \cdot \frac{s_{r,zebra}}{1{,}0 + (x - \Delta)} - a \tag{5.17}$$

$$a_{m,cl,regular} = 0{,}2 \cdot \frac{s_{r,regular}}{0{,}2 + (x - \Delta)} - a \tag{5.18}$$

$a$ actual distance walking line – sight limiting object sideways [m]

$a_{m,cl}$ missing distance walking line – sight limiting object sideways for a safe crossing if the curb was extended to the lane [m]

$s_r$ required sight distance [m]

$x$ Distance curb – middle of the approaching lane (= where the driver is assumed to be) [m]

$\Delta$ Distance curb – sight limiting object forward (positive values for bigger parking lanes) [m]

### 5.1.3 Results

34 of the 100 recorded curb extensions were at zebra crossings, 66 at regular ones. At 78 sites the speed limit was 30 km/h, at 22 sites 50 km/h were allowed.

Extensions were found with a width ranging from 0,9 m to 4,8 m. In relation to the parking lane, the largest group were extensions ending 20 cm away from the lane (20%) followed by extensions with the same width as the parking lane (17%). The biggest gap found between curb and lane was 2,7 m.

At every recorded curb extension, one sight limiting object was identified. In 94 of the 100 cases parking cars were the sight limiting objects. Objects located right at the curb extension were found only twice. This does not mean that there were no objects such as phone boxes, bicycle parking, dustbins, etc. located at curb extensions in Vienna, but that almost everywhere the parking lanes were more limiting.

The measured speeds showed two things. On roads with a 30 km/h limit, the $v_{85}$ was mainly higher, but on streets with a limit of 50 km/h, it was slightly below. At intersections with mandatory turning the speeds were lower.

Of the 100 sites 19 complied with the RVS and 81 failed. Due to the not random sample this allows no statement about the general situation in Vienna. Detailed results for every recorded curb extension can be found in appendix A.

For crossings with insufficient visibility ranges it was checked if the RVS would be fulfilled when the curb reached out right to the lane. For zebra crossings this would have helped in 4 of the 28 cases (14%), at regular crossings in 32 of 51 cases (63%).

This difference results in the five times bigger distance of the waiting pedestrian from the curb.

For curb extensions at intersections it was separately recorded, if the curb on the walking line was set back due to the turning radii. In fact, 40% of the curb extensions had a reduced width at the walking line as a result of rounded corners. The necessity of such big turning radii was not checked in this thesis.

## 5.2 Pedestrian behaviour

### 5.2.1 Method

The behavioural analysis had two goals. It was tried to identify some patterns in pedestrian behaviour on the one hand and on the other hand to take a detailed look at the exact stopping points. Those informations should help explaining why people stop where they stop. It was differentiated between the distance to the curb and the distance to the lane. The difference between those distances is described in figure 1.1.

Most of the time, pedestrians were observed by video analysis. This was necessary due to the high pedestrian traffic volumes. Just few minor crossings with less pedestrians or vehicles were watched, because too little people stopped there in a reasonable period.

Similar problems occurred at zebra crossings, even with high pedestrian and car volumes. As almost every vehicle gave way to approaching pedestrians, almost no stoppings could be recorded at zebra crossings.

The stopping percentage of pedestrians and cars was recorded. The locations observed in this thesis do not allow a comparison of stopping rates.

What was not recorded is the vision of pedestrians or car drivers, when making the decision to cross or to stop. It was tried to check the point where the pedestrians were looking down the street, but on the one hand, some pedestrians did not roll their head and on the other hand, when they did it on the move, the exact point could not be determined. It was assumed that pedestrians always go to a spot where they mean to see enough before deciding whether to go or not. With this method the necessary sight distances mentioned in the guidelines can not be evaluated.

**Accident history** For all five locations all accidents reported by the police in five years (2010 - 2014) were analysed. A more detailed look was taken at accidents with pedestrians involved.

### 5.2.2 Locations

**Site 1: Reumannplatz / Ettenreichgasse**

Vienna, N 48.1731° | E 16.3771°
Observation period: 50 minutes

**Characteristics** The intersection lies in a little bend of the two laned one way street *Reumannplatz*. Three curb extensions were observed, all crossing *Reumannplatz*, see figure 5.1. Due to the bend, pedestrians coming from south (*Ettenreichgasse*) easily overlook the street. Next to the extension is a former parking lane that was abandoned to ensure visibility. It is now blocked with a 60 cm high concrete block. The first legal position of a parking vehicle is 7,5 m away (parallel parking).

The main relation of pedestrians is from *Ettenreichgasse* (south) to the underground station at *Reumannplatz* (north). Both sidewalks of *Ettenreichgasse* showed high pedestrian volumes.

The vehicles passing by always came in blocks due to traffic light at Favoritenstraße ($\sim$ 100 m away). Between those blocks, almost no cars passed by and allowed a safe crossing of the street.

In *Ettenreichgasse* there is a school some blocks further south. During the observation period, at some points, groups of students passed by. They arrived in groups of 5 to 10 and were talking with each other. They didn't all line up at the curb but waited in rows. Students in the rear rows were almost never watching the traffic, they relied on their colleagues in front and their judgement of the situation.

**Accident history** 11 accidents in 5 years with physical injuries (2 involving pedestrians). Main type of car accidents were cars coming from Ettenreichgasse (south) which didn't give way to cars coming from Reumannplatz (east).
Pedestrian accident #1: Pedestrian (female, 76 years) crossing from northwest to southwest. Car driving backwards from west. Pedestrian seriously injured.
Pedestrian accident #2: Pedestrian (female, age unknown) crossing from northwest to southwest. Car coming from east. Pedestrian and driver not injured, passengers slightly injured.

**Findings** Figure 5.1 shows the situation at the intersection. Cars are approaching from the right. Both curb extensions at the south side of the street have a good view at the approaching cars. Due to a bend, pedestrians crossing from north to south see less, but still enough to ensure a safe crossing.

All three extensions reach out right to the lane. This explains the few stopping points off the curb (at the lane). The two extensions south with good sight show

Table 5.2: Traffic flows at Reumannplatz / Ettenreichgasse / Davidgasse

| pedestrians $SE \rightarrow N$ | absolute | per hour | percent |
|---|---|---|---|
| stop | 76 | 91 | 50% |
| no stop | 75 | 90 | 50% |
| **total** | **151** | **181** | **100%** |

| pedestrians $SW \rightarrow N$ | absolute | per hour | percent |
|---|---|---|---|
| stop | 76 | 91 | 39% |
| no stop | 119 | 143 | 61% |
| **total** | **195** | **234** | **100%** |

| pedestrians $NE \rightarrow S$ | absolute | per hour | percent |
|---|---|---|---|
| stop | 70 | 84 | 42% |
| no stop | 97 | 116 | 58% |
| **total** | **167** | **200** | **100%** |

| vehicles $E \rightarrow W$ | absolute | per hour | percent |
|---|---|---|---|
| stop for pedestrian | 3 | 4 | 1% |
| no stop | 389 | 467 | 99% |
| **total** | **392** | **471** | **100%** |

a scattered distribution of stopping points. The stopping points north are mainly focused right at the curb (= lane) in the walking line.


Figure 5.1: Reumannplatz / Ettenreichgasse

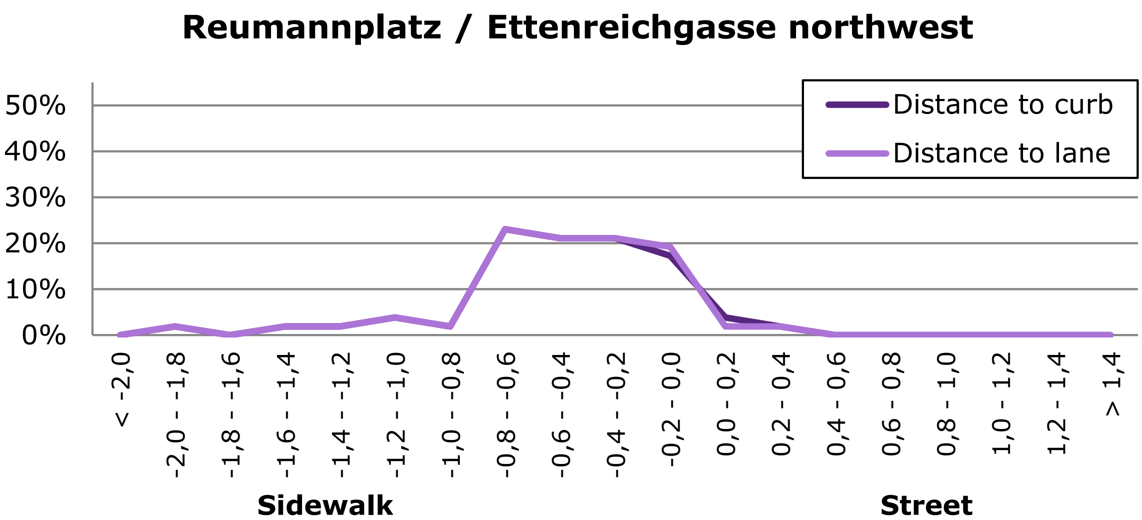


Figure 5.2: Distribution of stopping points
Reumannplatz / Ettenreichgasse northwest

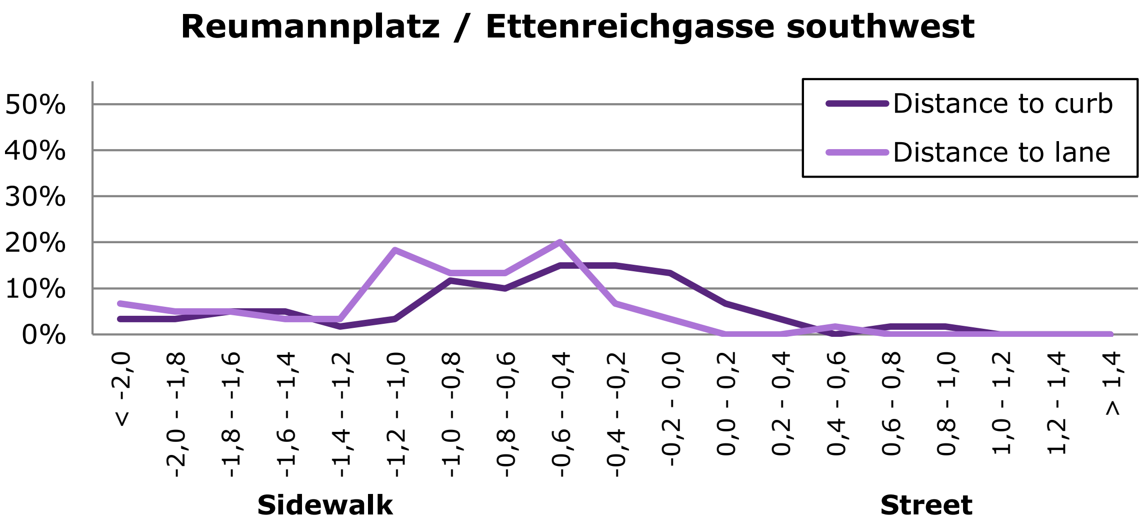


Figure 5.3: Distribution of stopping points
Reumannplatz / Ettenreichgasse southwest

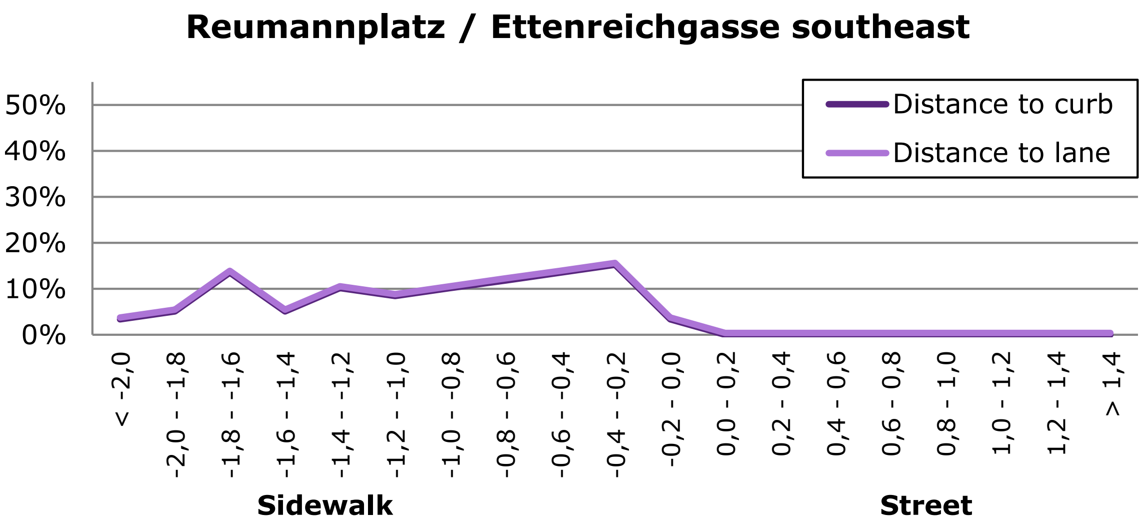


Figure 5.4: Distribution of stopping points
Reumannplatz / Ettenreichgasse southeast

**Site 2: Hütteldorfer Straße / Hickelgasse**

Vienna, N 48.1990° | E 16.3103°
Observation period: 30 minutes

**Characteristics** At *Hütteldorfer Straße* there is a 23 m long curb extension. It is at the end of a (not signalized) pedestrian zone and has many amenities from shopping, education and living around.

The speed limit in *Hütteldorfer Straße* is set at 50 km/h, the measured speed was with 43 km/h lower than that. As the location is situated at the open track of a tram line, it is not allowed to install a zebra crossing without traffic lights.

The long curb extension provides good sight to both directions. But as the street is very wide (> 8 m) at the location, the necessary sight distances are very long too (> 60 m). Due to the wide street, few cars are passing close to the curb. The area 1 m in front of the extension was almost never overran by cars during the observation period.

**Accident history** 3 accidents in 5 years with physical injuries (all 3 involving pedestrians). Two accidents happened across *Hickelgasse*, just one accident happened with a pedestrian crossing *Hütteldorfer Straße*.
Pedestrian accident #1: Pedestrian (male, 22 years) crossing from southwest to northwest. Car driving from east to west. Pedestrian slightly injured.

**Findings** A look at figure 5.5 shows, that the whole length of the extension was used to cross the street. Due to rather good visibility, many pedestrians stopped slightly before the curb in a safer environment. On the other hand, some stepped off the curb, because no cars passed this area.

It was observed that some pedestrians started to cross when no cars were coming from left, but there was no free gap in the line of vehicles coming from right. The pedestrians then slowed down, until a car driver stopped and let them pass.

Another observation was made at the location. Sometimes several pedestrians were waiting to cross. It was more than once, that some of the waiting pedestrians crossed, when others did not react and waited for a bigger gap in the traffic flow.

**Waiting time and speed** During the observation period, this crossing was used by all age groups and was – in comparison to other sites with many recorded stoppings – little influenced by group behaviour or cars coming in blocks. This led to the decision to do a more detailed analysis of pedestrian behaviour at the site.

For all stoppings, the waiting time was recorded as well as the pedestrian walking speed. The waiting time was classified into four groups: <1 s, <5 s,<10 s and >10 s.

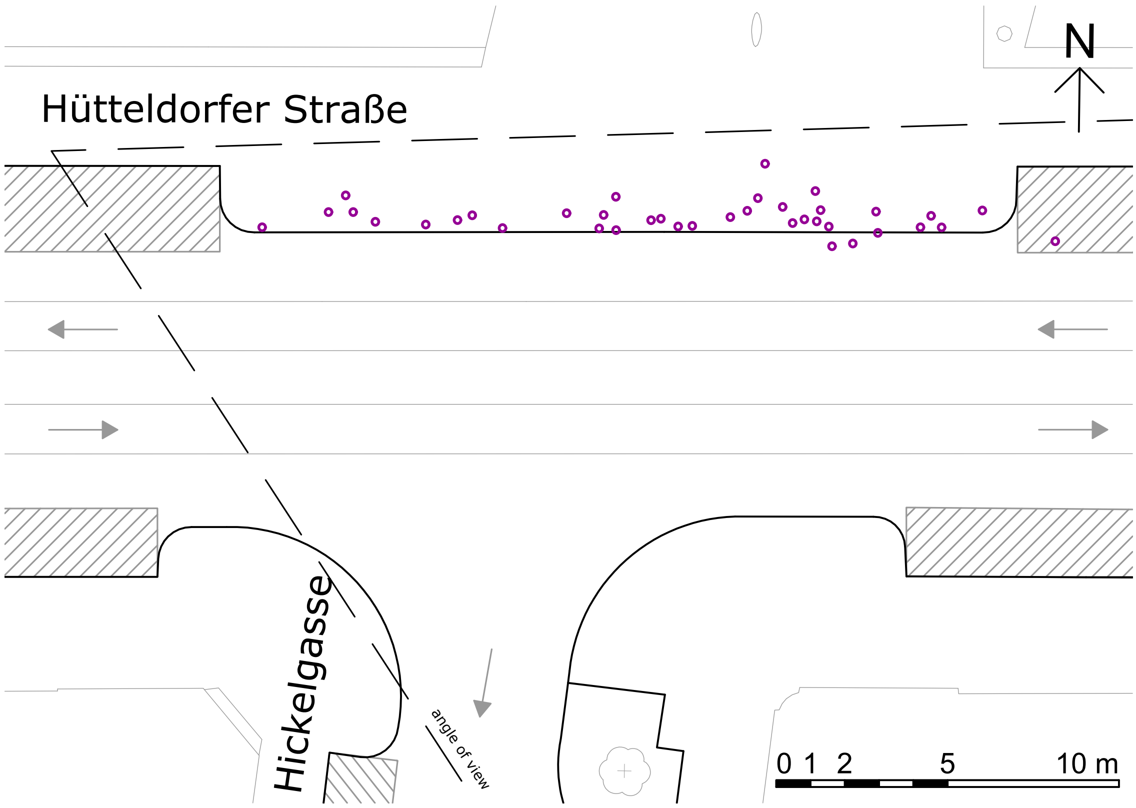


Figure 5.5: Hütteldorfer Straße / Hickelgasse

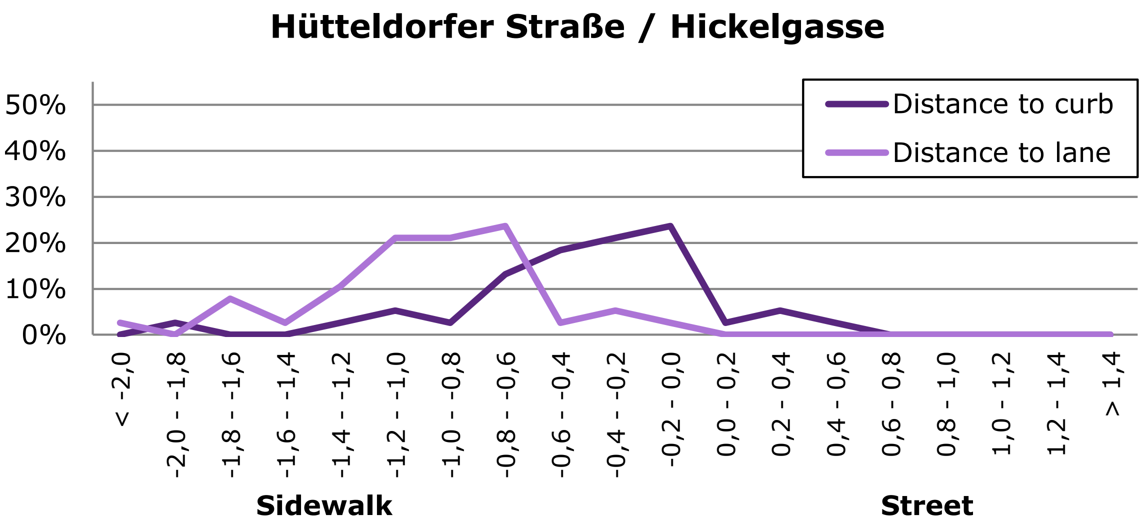


Figure 5.6: Distribution of stopping points
Hütteldorfer Straße / Hickelgasse

Table 5.3: Traffic flows: Hütteldorfer Straße / Hickelgasse

| pedestrians $N \rightarrow S$ | absolute | per hour | percent |
|---|---|---|---|
| stop | 38 | 76 | 61% |
| no stop | 24 | 48 | 39% |
| **total** | **62** | **124** | **100%** |

| vehicles $E \rightarrow W$ | absolute | per hour | percent |
|---|---|---|---|
| stop for pedestrian | 3 | 6 | 2% |
| no stop | 187 | 374 | 98% |
| **total** | **190** | **380** | **100%** |

| vehicles $W \rightarrow E$ | absolute | per hour | percent |
|---|---|---|---|
| stop for pedestrian | 1 | 2 | 1% |
| no stop | 179 | 358 | 99% |
| **total** | **180** | **360** | **100%** |

The walking speed was not measured directly, as it wasn't possible with this observation method. It was decided by the observer if a person was walking with an average speed, significantly slower or faster. People who changed speed, were given the maximum speed. For example if they slowly entered the street, but started running in the middle, they were classified as fast. In total 38 stoppings were recorded.

**Pedestrian waiting times** The class with the most recordings was the >10 s waiting time (16 times). Below 10 s and <5 s were seen about the same (9–10 times), short stops <1 s just 3 times. The distribution of stopping points classified by waiting time can be seen in figure 5.7.

The short stops of less than 1 s were all exactly at the curb. In all cases the path was free to cross, but the pedestrians hadn't looked for approaching vehicles before they reached the curb. The more common stopping durations show an interesting distribution. The more the pedestrians waited on the right side (pedestrians' view), the better sight they had for vehicles passing right in front of the curb (coming from left). Pedestrians waiting further right were stopping for shorter times than those waiting at the left side of the curb extension. Stops of less than 5 s were observed mainly on the right half of the extension, stops between 5 and 10 s in the middle and stops over 10 s mainly at the left end of the extension.

Almost no cars stopped for pedestrians, nearly all crossings happened in gaps between the vehicles.

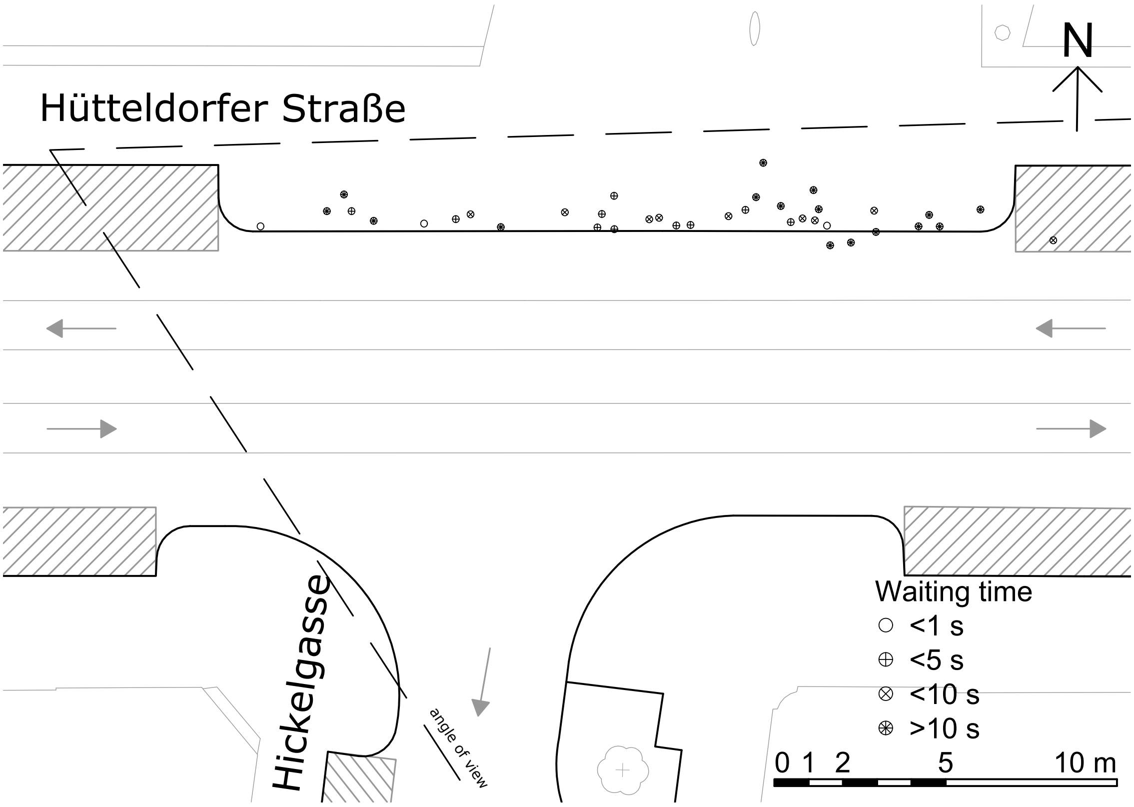


Figure 5.7: Hütteldorfer Straße / Hickelgasse: waiting times

**Pedestrian crossing speed** The distribution of stopping points with the pedestrian walking speed can be seen in fig. 5.8. Seven slow and seven fast walkers were recorded besides 24 with an average walking speed. The distribution of stopping points and pedestrian speed shows no correlation. All three speeds are found at all sides of the curb extensions and with all distances away from the curb. One trend that could be derived from the graphic is that slow pedestrians rather cross in the middle of the extension, where they have the best view to both sides of the street. But the sample is too small to proof this hypothesis.

**Comparison of waiting time and speed** A comparison of both variables is provided in table 5.4. The observed behaviour of slower pedestrians waiting longer than the faster ones can not be found there.

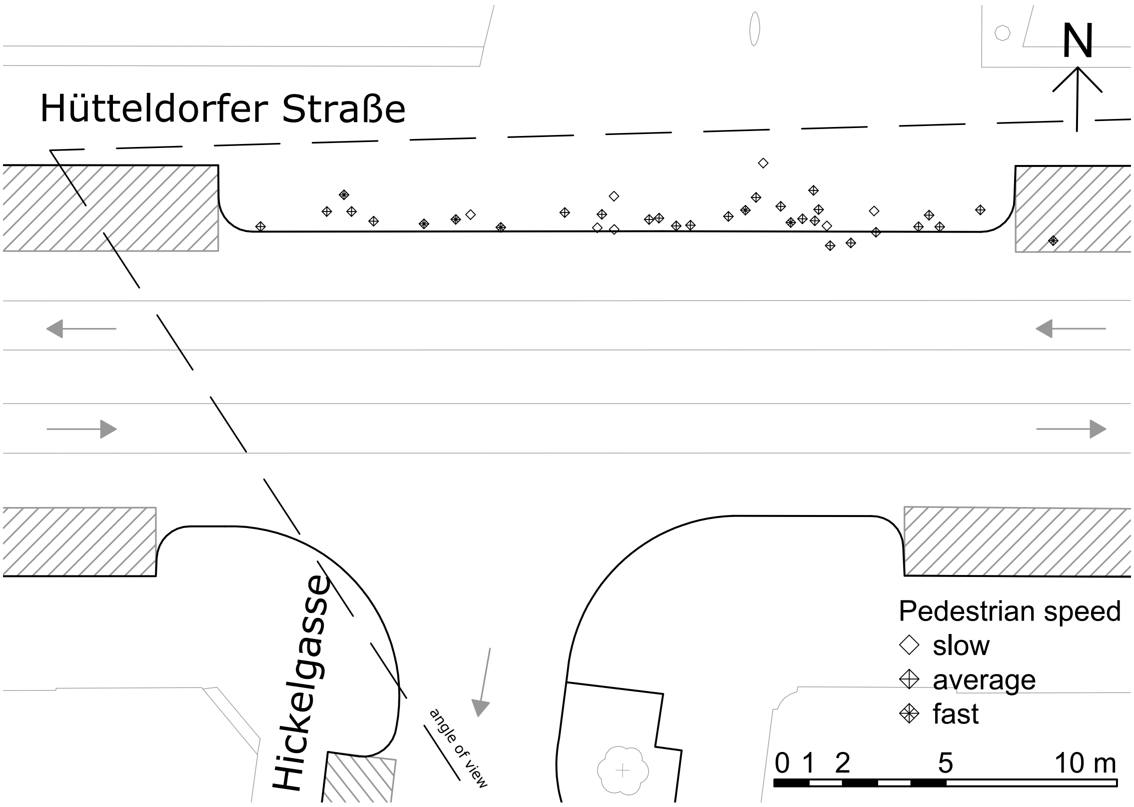


Figure 5.8: Hütteldorfer Straße / Hickelgasse: pedestrian crossing speed

Table 5.4: Observed waiting times and walking speed

| | | waiting times | | | | |
|---|---|---|---|---|---|---|
| | | <1 s | <5 s | <10 s | >10 s | **sum** |
| **speed** | slow | 1 | 3 | 2 | 1 | **7** |
| | average | 1 | 4 | 6 | 13 | **24** |
| | fast | 1 | 3 | 1 | 2 | **7** |
| | **sum** | **3** | **10** | **9** | **16** | **38** |

**Site 3: Beckmanngasse / Märzstraße**

Vienna, N 48.1964° | E 16.3139°
Observation period: 30 minutes

**Characteristics** The observed curb extension is a regular crossing. All streets lie in a 30 km/h zone and there are no priority signs, therefore the right of way counts for the right hand side. The measured speed in *Märzstraße* was at 38 km/h, which is clearly above the limit. Due to low traffic volumes in *Beckmanngasse*, speed was not measured there. It was assumed to be about the same.

Adjacent to the curb extension, there is a former parking lot which is now used as a place for a big dustbin. The dustbin is located close to the sidewalk an does not impair the visibility. Next to this, there is a tree, followed by a diagonal parking lane. The curb extension's width is the same as the parking lane's, but due to the curb radius there is a little offset, depending on the walking line. In total, the visibility is classified as good and compliant to the RVS. As *Märzstraße* has a slight distortion at the intersection, the curb extension lies directly in the line of cars approaching from left, which leads to a perfect visibility.

The location is close to a school and was observed just before school start in the morning. Most of the pedestrians were children. The school, which was the main destination of the pedestrians, is located in *Beckmanngasse* further north at the west side. So everybody who crossed *Märzstraße* from the observed extension still had to cross *Beckmanngasse* as well. About half of the pedestrians crossed right at the intersection, the other half crossed in front of the school. A minority first crossed *Beckmanngasse* and then *Märzstraße*.

**Accident history** 1 accident in 5 years with physical injuries (not involving pedestrians).

**Findings** It was observed that every stopping pedestrian went right up to the curb. The only exception were children in groups too big to walk next to each other.

At this location a children-related behaviour was identified. More than once, small children (6 to 10 years old) approached to the edge of the curb without looking at the crossing traffic. After coming to a complete stop, they took a look and decided to continue or wait. Once they saw an approaching car, they let it pass, even when it was far away and they could have crossed easily before the car had arrived. Older children (>10 years) did not show this behaviour. They took a look while approaching the intersection and often did not stop at all. The stopping points are shown in figure 5.9.

As this location was not videotaped, no traffic volumes were recorded.

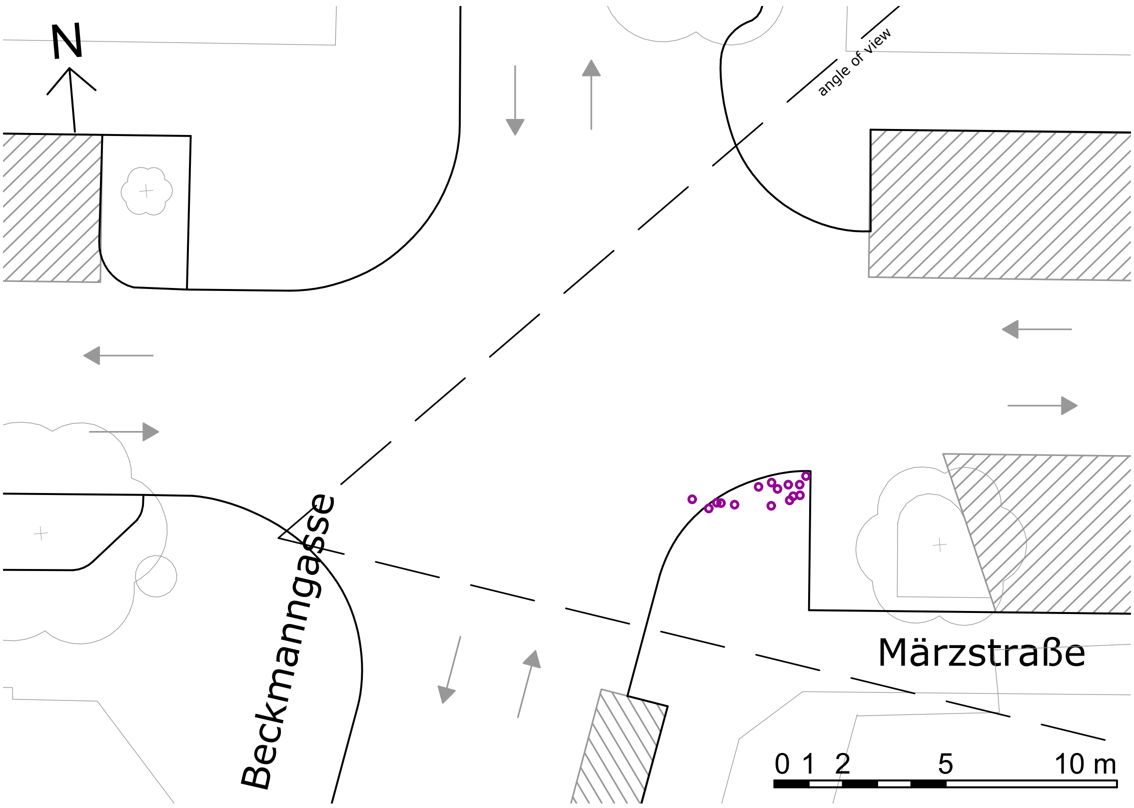


Figure 5.9: Beckmanngasse / Märzstraße

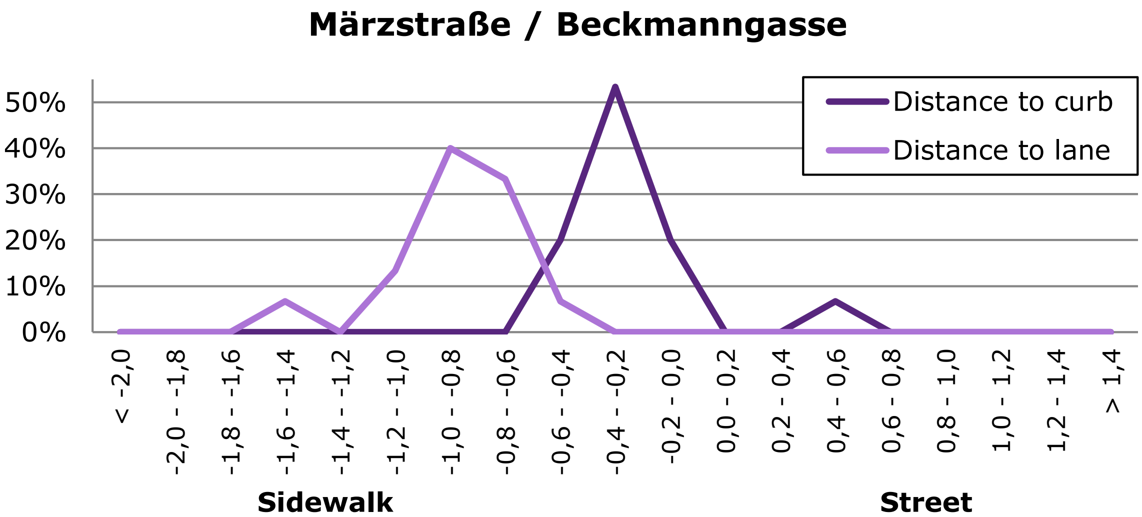


Figure 5.10: Distribution of stopping points
Beckmanngasse / Märzstraße

**Site 4: Reinlgasse / Märzstraße**

Vienna, N 48.1966° | E 16.3121°
Observation period: 24 minutes

**Characteristics** The location is close to a school. In *Reinlgasse* the speed limit is set at 50 km/h, the measured speed lies slightly below that. In Märzstraße the speed limit is set at 30 km/h but, as vehicles coming from Märzstraße have to give way, the approaching speed is lower.

There is a tram line going through *Reinlgasse* which has a stop right at the intersection. The stations are, for both directions, right before the crossing.

There are zebra crossings across *Reinlgasse* and regular crossings across Märzstraße. There are curb extensions on all 8 edges of the intersection. The observed curb extension (nr. 5 in the layout analysis) is 1,8 m wide, which is 0,2 m less than the adjacent parking lane. The sight distance to the left (intersection oriented) was very good. The sight distance to the right was limited by a parked car, which could be overlooked by adults but not by children. Children had to advance very close to the curb to get enough vision of approaching cars. Due to the zebra crossings, most of the cars stopped to let the children pass. Only few pedestrians stopped at the crossing, most walked right through.

The observation period was in the morning just before school start. Most of the pedestrians were children in groups, children with parents and children walking alone.

**Accident history** 8 accidents in 5 years with physical injuries (2 involving pedestrians).
Pedestrian accident #1: Pedestrian (female, 16 years) crossing from southeast to southwest. Car driving from south to north. Pedestrian slightly injured.

**Findings** It was noticeable, that stopping children oriented themselves at the curb almost all the time. It would have been pretty safe to take a little step at the street (20 cm) to get better sight, because there was a car parking right next to them reaching out that far. But no child showed such a behaviour.

For adults, this phenomenon could not be observed, because they could overlook the parked car and therefore had no improvement in sight by stepping out onto the street.

Children in company of adults did not try to decide on their own when it was safe to cross, they followed the adults' decision.

In figure 5.11 two groups of dots can be seen. One represents the children stopping right at the curb while not touching the lane. The other group represents

Table 5.5: Traffic flows: Reinlgasse / Märzstraße

| pedestrians $W \rightarrow E$ | absolute | per hour | percent |
|---|---|---|---|
| stop | 16 | 40 | 41% |
| no stop | 23 | 58 | 59% |
| **total** | **39** | **98** | **100%** |

| vehicles $N \rightarrow S$ | absolute | per hour | percent |
|---|---|---|---|
| stop for pedestrian | 5 | 13 | 8% |
| no stop | 64 | 160 | 92% |
| **total** | **69** | **173** | **100%** |

| vehicles $S \rightarrow N$ | absolute | per hour | percent |
|---|---|---|---|
| stop for pedestrian | 13 | 33 | 17% |
| no stop | 64 | 160 | 83% |
| **total** | **77** | **193** | **100%** |

adults (sometimes accompanied by children) waiting at a safe distance to the curb for a safe crossing.

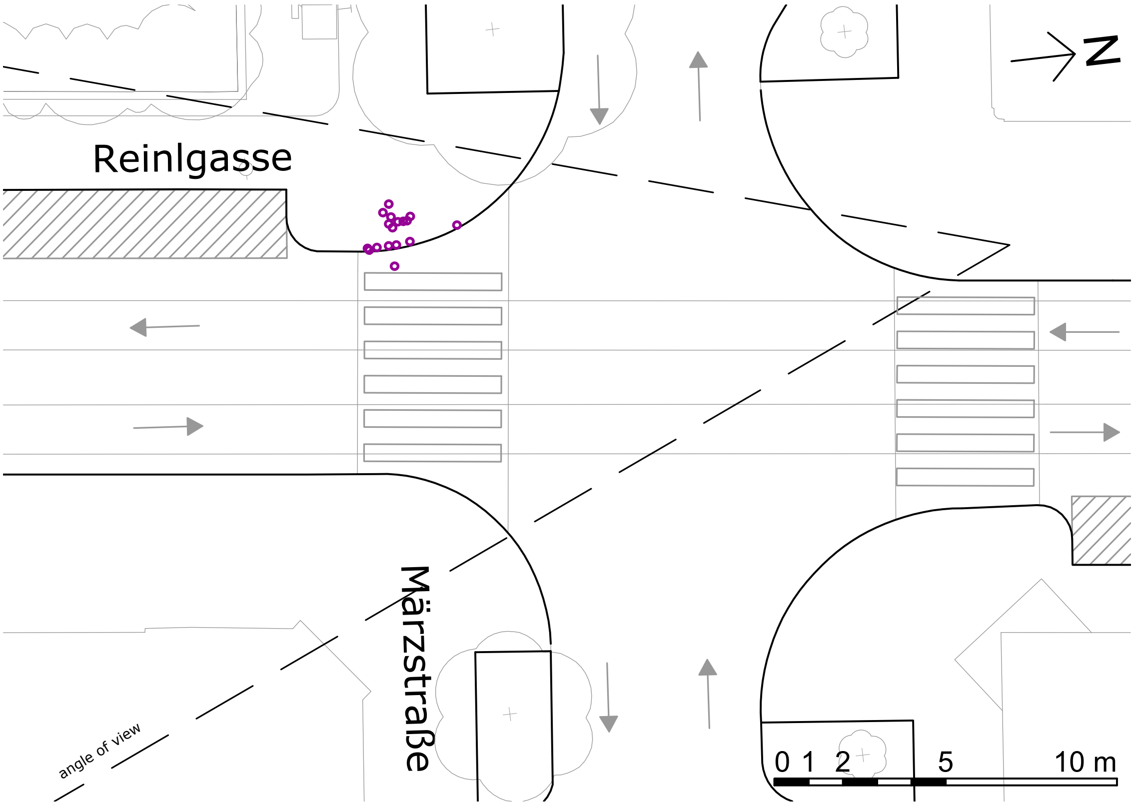


Figure 5.11: Reinlgasse / Märzstraße

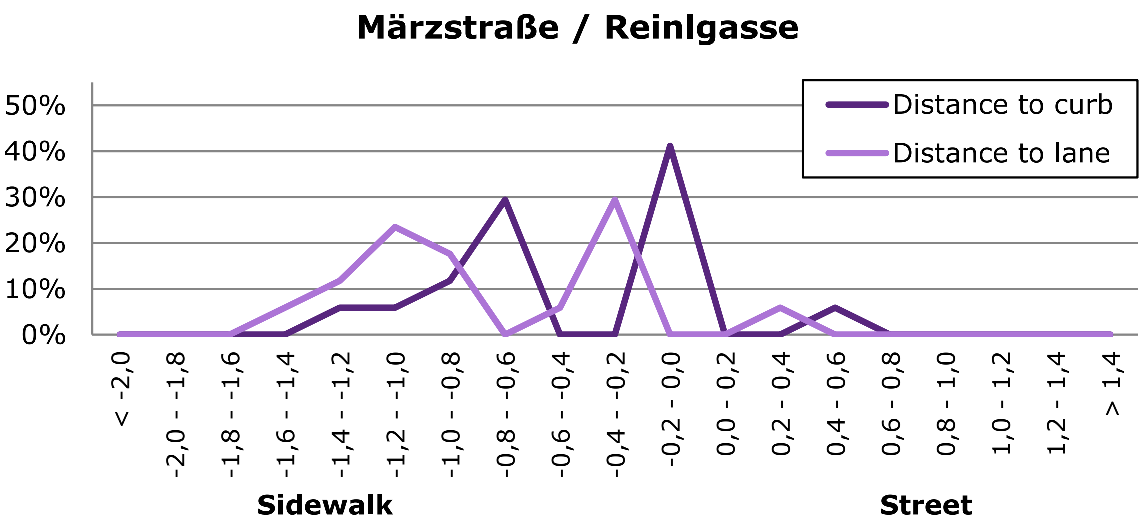


Figure 5.12: Distribution of stopping points
Reinlgasse / Märzstraße

**Site 5: Stumpergasse / Schmalzhofgasse**

Vienna, N 48.1944° | E 16.3439°
Observation period: 30 minutes

Table 5.6: Traffic flows at Stumpergasse / Schmalzhofgasse

| pedestrians $S \to N$ | absolute | per hour | percent |
|---|---|---|---|
| stop | 2 | 4 | 4% |
| no stop | 49 | 98 | 96% |
| **total** | **51** | **102** | **100%** |

| pedestrians $N \to S$ | absolute | per hour | percent |
|---|---|---|---|
| stop | 3 | 6 | 5% |
| no stop | 55 | 110 | 95% |
| **total** | **58** | **116** | **100%** |

| vehicles $E \to W$ | absolute | per hour | percent |
|---|---|---|---|
| stop for pedestrian | 18 | 36 | 13% |
| stop behind vehicle | 7 | 14 | 5% |
| no stop | 116 | 232 | 82% |
| **total** | **141** | **282** | **100%** |

**Characteristics** This T-junction has a zebra crossing across *Schmalzhofgasse* and one across *Stumpergasse* (south side). No cars are approaching from *Stumpergasse* due to one way regulations. Only bicycles may approach from the south (and have priority). The speed limit is set at 30 km/h in all streets, but, due to the intersection layout, vehicles in *Schmalzhofgasse* were approaching at lower speeds. The speed measurement was taken when approaching vehicles were approximately the necessary sight distance away from the zebra crossing. The $v_{85}$ at this point was set at 30 km/h.

At the curb extension north, there are two phone boxes situated between walking line and adjacent parking lane. Those objects did not allow to see through. For smaller pedestrians in addition, there also was a dustbin on a traffic sign, which limited visibility even more.

The parking lane is 2,0 m wide, which is 0,5 m wider that the curb extension's width. At the other side of the crossing, there is a diagonal parking lane. Due to the curb radius the sight distances from south were pretty bad. However, there was a tree planted between curb extension and parking lane, which improved the sight distance. Both curb extensions showed insufficient visibility of waiting and approaching pedestrians.

The main relation of pedestrian flow is in *Stumpergasse*. Main attractor is the underground station further north. Observation time was in the afternoon where more pedestrians were walking south.

The car traffic volumes were quite high. When a vehicle stopped at the intersection, most of the time following ones closed up.

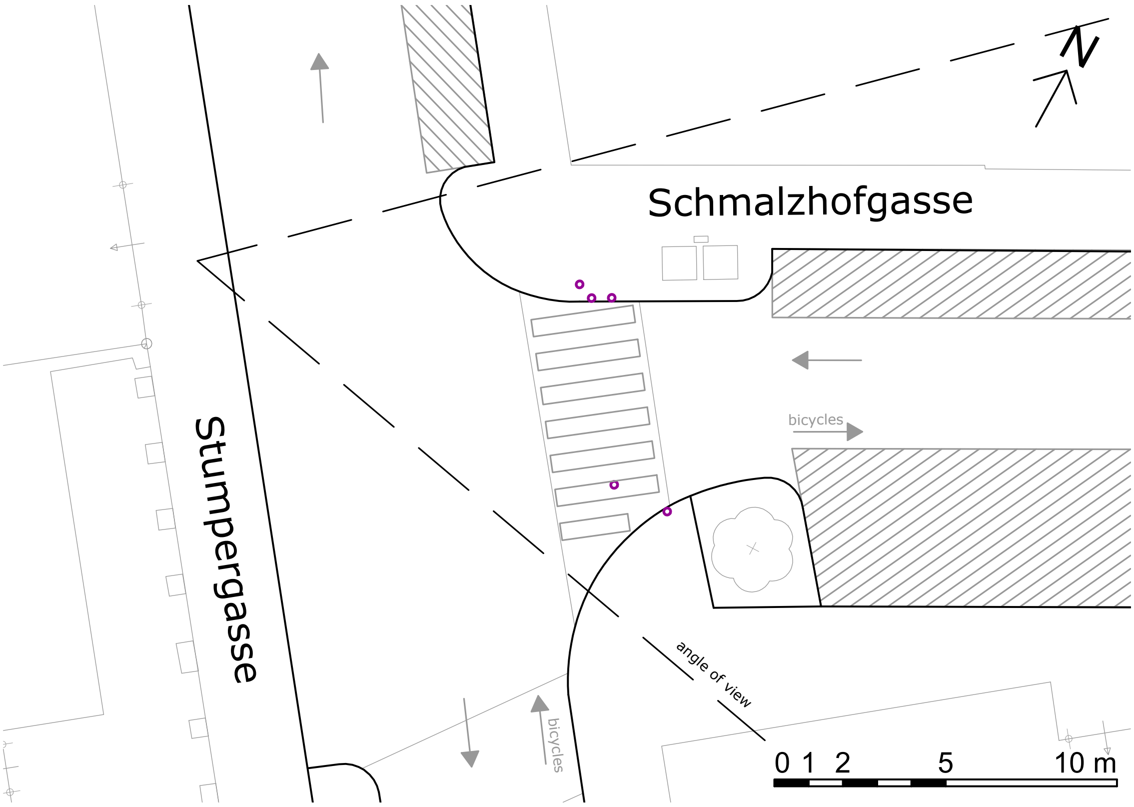


Figure 5.13: Stumpergasse / Schmalzhofgasse

**Accident history** 2 accidents in 5 years with physical injuries (none involving pedestrians).

**Findings** Even during the rush hour with high car and pedestrian traffic volumes very few stopping pedestrians were observed. In 30 minutes only 5 stops were recorded at both extensions.

This shows that even on curb extensions with insufficient visibility, it is possible for pedestrians to cross without coming to a complete stop. It often was observed, that pedestrians lowered their speed to let a car pass before they started to cross. Another situation that occurred, was that cars were already standing due to either preceding pedestrians or bicycles they gave way to. In those situations pedestrians could walk right through without changing their speed at all.

If this crossing wouldn't have been a zebra crossing, it is assumed that the number of stopping pedestrians would have been higher.

### 5.2.3 Results

**Distribution of stopping points**

All diagrams shown in section 5.2.2 are overlaid in four graphics. For both, distance to the curb and distance to the lane, there are diagrams showing ordinary and cumulative curves.

Figure 5.14 and 5.16 contain all lines showing the distribution of stopping points in relation to the distance to the curb. Figure 5.15 and 5.17 show the distributions as distance to the lane.

**Distance to the curb** The six locations show varying distributions of stopping points away from the curb. The peaks are between 0,0 and 0,8 m away from it. The single peaks of the different locations range from 15% to 55%. At one site (*Beckmanng. / Märzstr.*) there is a clear peak. *Reinlg. / Märzstraße* has two peaks. The other observed curb extensions did not show clear peaks, rather a range of a distance of about one meter where most pedestrians stopped.

All six locations show a sharp drop in the number of stopping points at the curb. Only few pedestrians were seen waiting off the curb to cross the street. At the other side, away from the curb, the distributions do not show such a clear point at which the stopping area ends for the most. The values are developing asymptotically, some pedestrians stopped even 2 m away from the curb.

When looking at the cumulative distribution of stopping points (fig. 5.16), it can be seen, that about 70% of pedestrians were waiting within 1,0 m away from the curb. About 10% were on the lane, about 20% were waiting further back, more than 1,0 m away from the curb.

**Distance to the lane** The distribution of stopping points in relation to the lane shows no well defined peaks. At most locations the highest share of 20 cm-ranges is around 20%. Most of the distributions show a flat peak between 0,0 and 1,0 m away from the lane. Almost no stops at the lane were recorded.

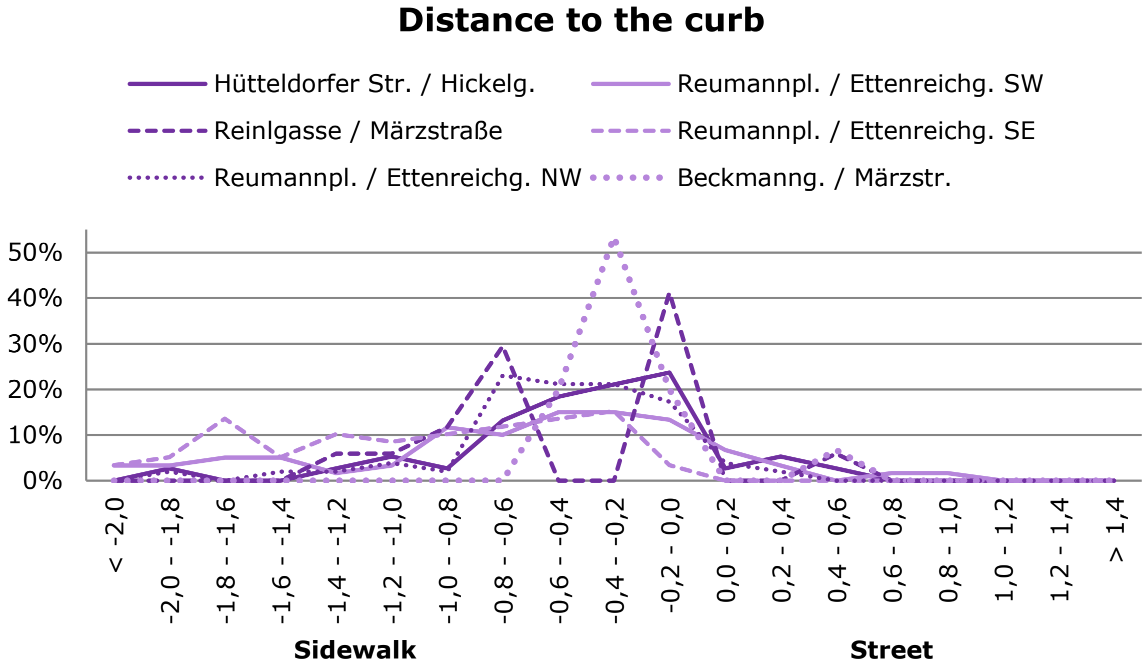


Figure 5.14: Distribution of stopping points at all analysed curb extensions, distance to the curb

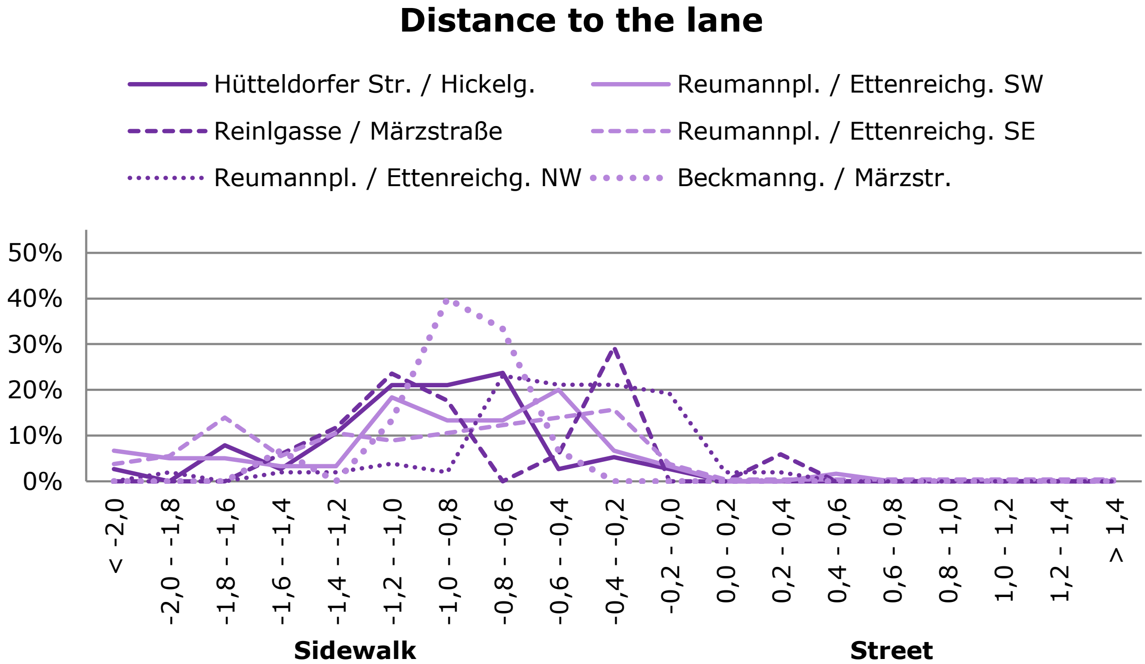


Figure 5.15: Distribution of stopping points at all analysed curb extensions, distance to the lane

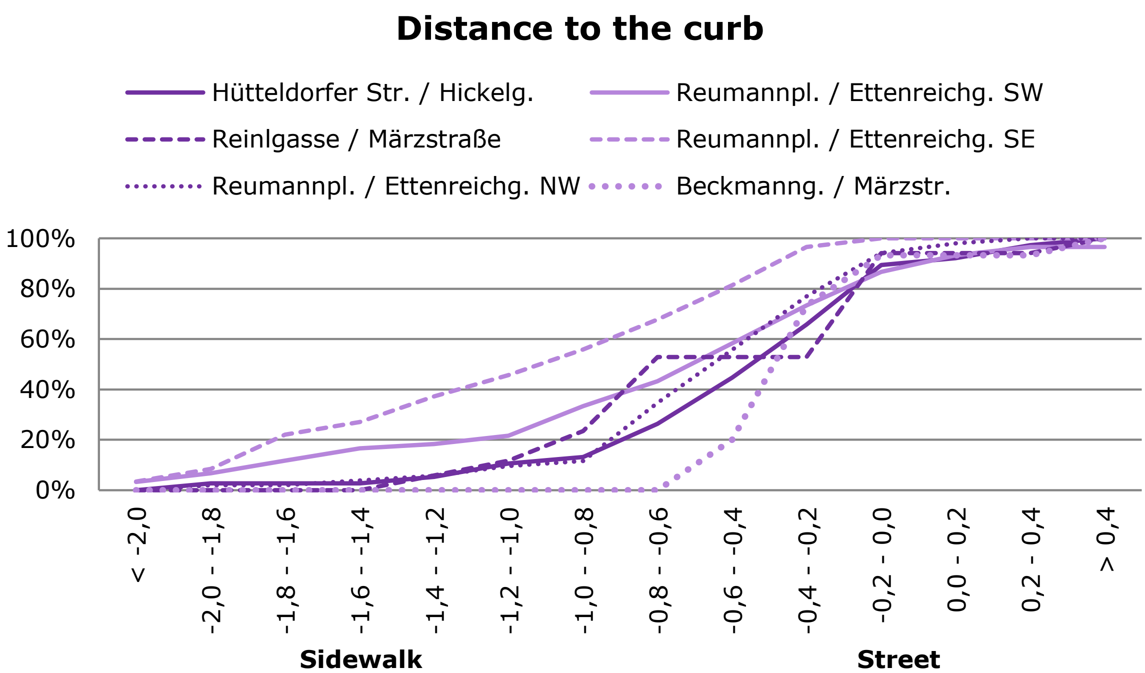


Figure 5.16: Cumulated distribution of stopping points: distance to the curb

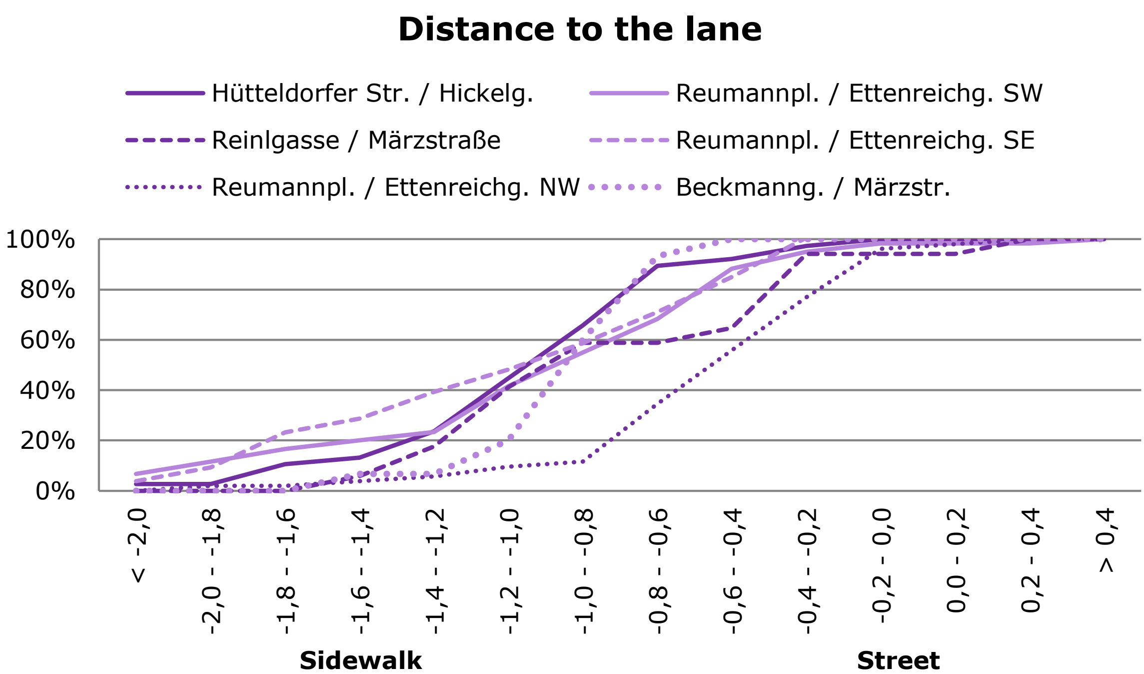


Figure 5.17: Cumulated distribution of stopping points: distance to the lane

The cumulative diagram (fig. 5.17) shows, that at some locations, 40% of stopping points are more than 1,0 m away from the lane. Almost no stopping points were recorded at the lane.

**Comparison** Both ordinary diagrams do not show any clear peak, but in general, the distribution of stopping points is more condensed in relation to the curb than to the lane. It can be concluded that pedestrians rather orient themselves at the curb, than at the lane. Therefore it makes a difference whether the curb extension reaches out to the lane or not. This finding confirms the assumption of all three compared countries' guidelines which put the waiting pedestrian in a defined distance away from the curb.

As neither the curb nor the lane show a clear and precise orientation of stopping pedestrians, more variables need to be checked. During the observations, some patterns in the behaviour of pedestrians waiting to cross the street were detected, which may explain the broad distribution of observed stopping points.

#### Groups

In pedestrian groups of more than three only the walkers in front were watching the traffic. People in the back did not show much interest in the vehicle traffic. They often did not take a look before entering the street, as they were following their leaders.

#### Irregular traffic flow

Intersections with traffic lights can influence subsequent crossings. On streets with high traffic volumes, the street can only be crossed safely in gaps caused by a precedent traffic light. It was observed that people knowing this scheme behaved like at a real traffic light. They didn't look for a gap, but rather waited for the gap they knew would come. The waiting positions were in a safe distance to the curb and the vehicles rushing past.

#### Influence of good visibility

At curb extensions with good visibility conditions, pedestrians were not stopping right at the curb, but at a safer distance. Particularly at streets with higher speeds, pedestrians were observed taking a step back from a spot they would have been secure anyway. Such behaviour was just seen where the surroundings provided enough sight even from the position after taking the step back.

The reason for this behaviour is not clear. One approach is that some people do not feel completely safe at curb extensions, even when those are secured with bollards. They could be afraid of either a car crashing into them or themselves stumbling and falling at the lane. Other possible explanations are the reduced impacts of noise and airstream caused by passing vehicles at a distant position.

The action of taking a step back did not lead to longer waiting times due to the longer crossing distance. Sometimes it even shortened the necessary time gap. It was observed that people waiting slightly away from the curb already started their motion before the last car passed. The pedestrians timed their walk, that they stepped at the street right after the car had passed but, due to the one or two steps they already had taken to reach the curb, they were moving at higher speeds than those pedestrians starting right from the curb. Therefore, the time at the street, from curb to curb, was shortened.

**Children**

Observations close to schools showed how children behave differently than adults. Parking cars obstruct children's vision more than adults'. Where adults see approaching vehicles across a parked car, children have to take some extra steps for the same vision.

Most of the children not accompanied by adults or in groups directly went to the curb and stopped. They did not try to judge the situation during the approach and maybe decide if they even have to stop. This was observed in situations where even children had good vision.

Many children waited in situations they could have crossed easily. This could be explained by a good traffic safety education.

**Influences on waiting time**

The obvious biggest factor on the time people had to wait were passing cars. But some differences were found within sites, meaning with the same circumstances.

It was observed at many locations, that sometimes people crossed while others did not. The first thought was, that this was a result of different walking speeds. But the analysis of waiting time and walking speed showed no correlation between those variables. It is possible, that the sample wasn't big enough, but other options need to be considered.

One point that will play a role for this question, is the capability of judging when the approaching cars will arrive at the crossing. People with bad vision for example will have problems to identify approaching vehicles from a distance and therefore will wait for bigger gaps in the traffic flow.

For other factors influencing pedestrians' judgement of approaching vehicles and gap selection, it is referred to Hamed (2001) and Oxley et al. (2005).

Another possible factor, that could explain the behaviour of pedestrians not choosing the same gap in the line of cars, is not the actual crossing speed, but the potential maximum walking (running) speed. In situations where it is unclear, if a car will arrive at the crossing before one could cross the street safely, fit people will take more risks than others. A fit person is more likely to enter the street in a situation where he might have to run the last meters to reach the other side safely. A person that cannot run, will not cross in this situation.

But when it turns out, that there is no need to run, nobody will, even the fit person will continue walking at an average speed. This example shows, that the actual crossing speed is not the only variable to explain different waiting times in same situations.

# Chapter 6

# Analysis

All three countries, Austria, Germany and Switzerland, cover curb extensions in their norms and guidelines. Nevertheless there is still room for improvement.

## 6.1 Extension width

### 6.1.1 Maximum width

As shown in section 4.4.3, there are different regulations regarding the curb extension width in relation to the adjacent parking lane's width. This section does not talk about the absolute width of the extension, but the relative width compared to the parking lane. It is clear that bigger extensions allow better visibility of pedestrians. Still, there are reasons to set a maximum width of curb extensions.

A minimum width of the street has to be provided to ensure, all vehicles fit through. This width depends on the street type and the driven speeds. All guidelines provide those measures.

In cases where the extension is far bigger than the parking lane, it could be misinterpreted as a signal not to park the cars parallelly but diagonally, which would lead to a worse visibility of pedestrians. This problem just occurs on very wide curb extensions, because the standard width of a 45° parking system (4,2 m) is more than double the width of a parallel parking lane (2,0 m). This problem is more academic than realistic.

The more realistic limit for curb extensions' widths is the danger of being overseen and run over by vehicles, which may result in damaged tyres or stumbling cyclists. For this reason, all guidelines recommend to improve the visibility through vertical objects such as bollards at the curb extension.

But where is the limit of curb extensions' widths? The Swiss standard sees 20 cm further than the parking lane as maximum, the Austrian one 20 cm less. The German standards even start at 30 cm further and end at 70 cm.

Designing curb extensions smaller than the parking lane's width cannot be the maximum width. The danger of overseeing a curb extension at an empty parking lane is almost non-existent. Either the parking lane is occupied (then it is impossible to hit the extension when driving straight on), or the parking lane is empty (then the driver has a perfect view of the extension and should recognise it early enough, at least when there are vertical elements for better visibility on the extension) – what does not happen very often in Vienna.

The danger of cyclists crashing into big curb extensions may be the bigger problem. Those accidents may result in physical injuries, which isn't the case when a car rolls over the curb with a tyre. Cyclists riding close to parked cars itself is dangerous, as reversing car drivers cannot see them properly and the risk of dooring is high. If curb extensions led cyclists to riding closer to the middle of the street, this would have positive effects on traffic safety. If the problem of cyclists crashing into curb extensions was real – data about that were not collected – further studies on how to defuse them by enhancing the visibility of the curb extensions should be made.

### 6.1.2 Relation of width and length

By widening curb extensions, they can be built much shorter and still provide the same sight distances. Let's take a zebra crossing at a one lane street (3,5 m wide) with 40 km/h driven speed. The necessary sight distance calculated by formula 5.2 is 33 m (in Austria).

When the pedestrian is waiting 20 cm off the curb and the curb extension is 20 cm wider than the parking lane, the pedestrian has an infinite sight at the approaching car. The necessary length of the curb extension is 0 m.

When the curb extension has the same width as the parking lane, there has to be a minimum length of the curb extension at the left side of the walking line, which is calculated by formula 6.1 to 3,4 m.

$$\frac{33}{0{,}2 + \frac{3{,}5}{2}} * 0{,}2 = 3{,}4 \tag{6.1}$$

If the curb extension is 20 cm smaller than the parking lane the free space between walking line and end of the parking lane can be calculated by formula 6.2 to 6,1 m. The reduction of the curb extension's width of 20 cm almost doubles the necessary length of the curb extension at the left side.

$$\frac{33}{\left(0{,}2 + \frac{3{,}5}{2}\right) + 0{,}2} * (0{,}2 + 0{,}2) = 6{,}1 \tag{6.2}$$

For the defined speeds 30, 40 and 50 km/h the necessary curb extension lengths (=distance to left from the walking line) can be read off figure 6.1. All three countries require minimal curb extension lengths. As Austria and Germany put the pedestrian in the middle of the crossing, half of this length is taken as minimum length at the left side, irrespective of the driven speeds. In Switzerland, there is no minimum length at the left side.

To ease the identification of the necessary free space at the left side for the most common curb extension widths, figure 6.2 was drawn. It shows the necessary free space at the left side depending on the driven speed according to the Austrian RVS. The diagrams are available for three extension widths: 0,2 m bigger, same width and 0,2 m smaller than the parking lane.

## 6.2 Position of the approaching pedestrian

At zebra crossings, the guidelines of all three countries set the waiting pedestrian 1,0 m away from the curb with no explanation of how this number developed. This leads to situations, where a pedestrian has to stop, or at least decelerate, when approaching a zebra crossing, even if the car driver is acting correctly.

For example: A car is driving 50 km/h and 45 m away from the crossing, which is the required sight distance in Austria. The driver sees the area 1 m next to the curb, but not more. Now, let's assume a pedestrian is approaching the crossing and is 2,0 m away from the curb. He cannot be seen by the driver. With a walking speed of 1,0 m/s he would enter the street in 2 seconds. During those two seconds, the car would continue driving with 50 km/h (14 m/s) and therefore would be $45 - (2 \cdot 14) = 17$ m away from the crossing. In the moment the driver recognises the pedestrian, it is too late to stop in front of the crossing, because he needed 45 m. Therefore the driver will continue, and the pedestrian has to wait for about a second until the car passes, before he is able to cross the street.

### 6.2.1 The premium crosswalk

At some crosswalks it might be reasonable to give pedestrians absolute priority. Those locations need much larger areas than 1,0 m in front of the curb, that can be seen by the car driver. For these crosswalks the term *premium crosswalk* is introduced.

The necessary distance from the pedestrian to the curb at premium crosswalks can be calculated. The time the pedestrian needs to get to the curb must be larger or the same as it takes the car to pass the crossing. In the example above, the pedestrian walks with 1,0 m/s. The car is 45 m away and moves with 14 m/s. It will

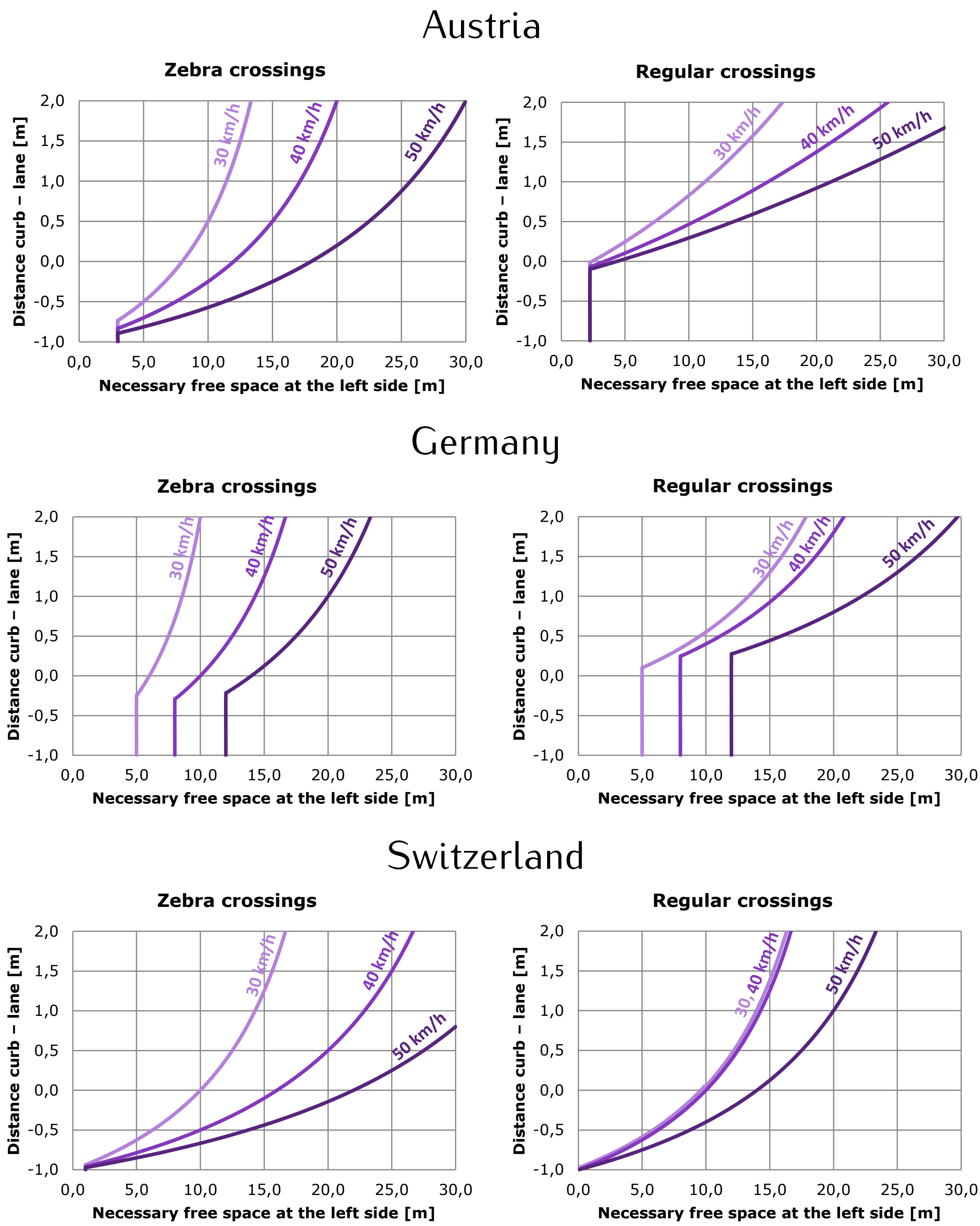


Figure 6.1: Necessary free space at the left side of the crossing dependent on the distance curb – lane

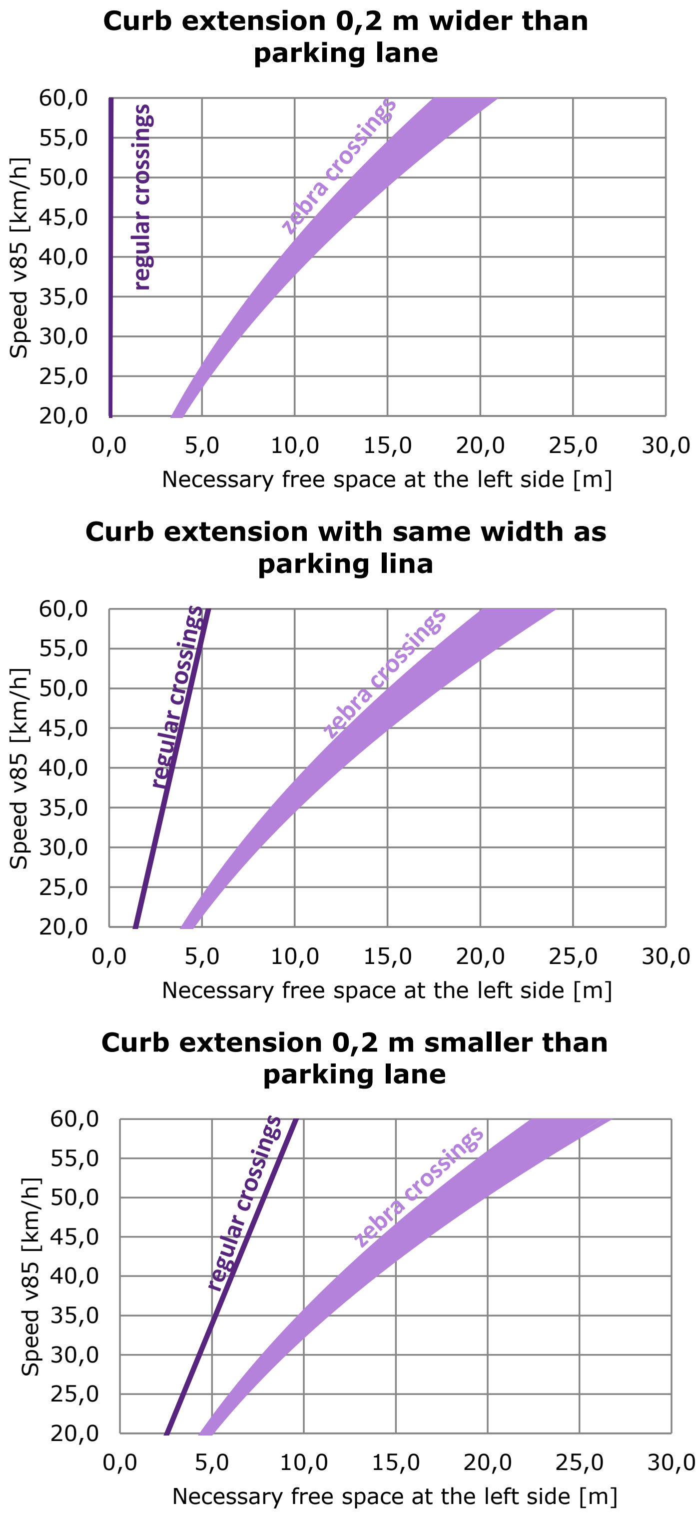


Figure 6.2: Relation extension length - speed, RVS

reach the crossing in 45/14 = 3,2 seconds. With a car length of 5 m and the width of the zebra markings of 4 m, it will be past the crossing in another 9/14 = 0,65 s.

The total time is therefore $3{,}2 + 0{,}65 \approx 3{,}9\,s$. Under the aspect, that the pedestrian should not have to wait at all, he must be recognisable 3,9 m away from the curb. A faster walking person would be even further away, a slower one closer.

To calculate the necessary distance for premium crosswalks, formula 6.3 can be used. Some lengths calculated by this formula are listed in table 6.1.

$$t = \frac{x + y + z}{v_c} \tag{6.3}$$

$$d = t \cdot v_p \tag{6.4}$$

$$d = \frac{x + y + z}{v_c} \cdot v_p \tag{6.5}$$

t Time to rush through = Time pedestrian is away [s]

x car stopping distance [m]

y car length [m]

z width of crossing [m]

d distance pedestrian is away [m]

$v_c$ car speed [m/s]

$v_p$ Pedestrian speed [m/s]

Table 6.1: Waiting area width for premium crosswalks, walking speed 1,0 m/s, car length 5,0 m, width of crossing 4,0 m

| Car speed [km/h] | Country | Stopping distance [m] | Necessary waiting area width [m] |
|---|---|---|---|
| 30 | AUT | 20 | 3,5 |
| 30 | GER | 15 | 2,9 |
| 30 | SUI | 25 | 4,1 |
| 40 | AUT | 30 | 3,5 |
| 40 | GER | 25 | 3,1 |
| 40 | SUI | 40 | 4,4 |
| 50 | AUT | 45 | 3,9 |
| 50 | GER | 35 | 3,2 |
| 50 | SUI | 55 | 4,6 |

# Chapter 7

# Recommendations

Guidelines for curb extension design should provide all information to guarantee same results. The minimum sight distances should be calculated for the actually driven speed, not the local speed limit.

It should always be tried to first reduce the speed and then design the curb extension. It is better to have smaller curb extensions and slower cars than fast cars and huge curb extensions.

## 7.1 Layout

Curb extensions should at least reach out to the lane. Smaller extensions than the parking lane should not be built. There is no maximum width in relation to the parking lane. If the curb reaches out further than the parking lane, it has to be made visible, in order to ensure that no cyclists or cars will crash into it.

Parking on curb extensions shall be prohibited by vertical elements, such as bollards.

Curb extensions have to be barrier-free. There has to be either a raised street (recommended) or a curb ramp to ensure that handicapped people can cross the street. The low curb should be set in the walking line, that no detours are necessary.

## 7.2 Sight distances

The recommended sight distances are seen as minimal values which have to be reached at all times. In most of the cases, longer sight distances will appear in reality, because many cars can be overlooked by pedestrians and vehicles often are not parked exactly at the edge of the markings. Most of the time, there will be at least a small space between parked car and curb.

Sight distances have to be kept clear by all objects. Exceptions can be made for vertical elements with a maximum diameter of 20 cm.

### 7.2.1 Waiting area

The sight distances should be achieved not for only one spot in the middle of the curb extension, but in a defined waiting area.

At zebra crossings the Swiss model is recommended. The area is 1,0 m wide and reaches out 1,0 m to the left and to the right beside the marked crosswalk (see fig. 4.6, page 30). A pedestrian has to be seen, when the car is the defined sight distance away from the markings.

At regular crossings the waiting area is recommended as follows: In front of curb ramps / raised lanes, the sight distances shall be achieved for a person standing 1,0 m away from the curb. This is necessary in order to give people with strollers or in wheelchairs the possibility of overlooking the situation. At spots with a high curb (next to the curb ramp), people are expected to – if necessary – stop right at the curb. From there, pedestrians will have better vision than from the waiting area (see figure 7.1).

The waiting area is always measured from the curb. In most cases this will be the same as from the lane (road markings), but at intersections with rounded corners it might not.

At corner extensions it is possible that the complete curb is lowered around the corner. In this case, another definition of the corner-sided border of the waiting area is needed. At such curb extensions, the waiting area is limited corner-sided by the extension of the sidewalk.

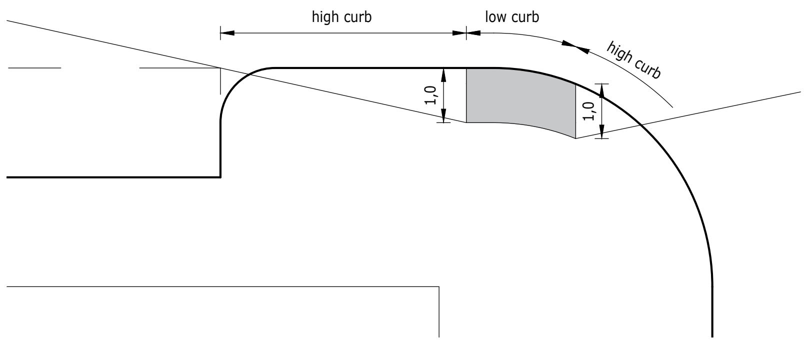


Figure 7.1: Recommended waiting area at regular crossings

At highly frequented zebra crossings it is recommended to install a premium crosswalk, see chapter 6.2.1.

### 7.2.2 Position of approaching vehicles and driver

The car driver is set in the middle of the vehicle (rectangular to the driving direction), a specified distance behind the bonnet. The point where an approaching car will be recognised by a pedestrian is defined at the middle of the vehicle front.
The middle of the vehicle (= position of the driver) within the lane is defined as follows:

| | |
|---|---|
| On the close lane | 1,5 m next to the parking lane. This is irrespective of the lane's width. |
| On the far lane | In the middle of the lane. |
| On bicycle lanes | In the middle of the lane. In the calculation of sight distances for cyclists the driven cyclists' speed may deviate from the car speed. |

### 7.2.3 Calculation

There should be two formulas, one for zebra crossings, one for regular ones. Both formulas should contain the *car speed* ($v_{85}$). At zebra crossings, it is necessary to define the *car driver's reaction time*, the *car deceleration* and the *distance from car driver to the car front*. Formula 7.1 shows the recommended sight distances at zebra crossings.

The calculation of sight distances at regular crossings also needs to include *crossing distance* (waiting position to end of lane (left side) or opposite curb (right side)) and *pedestrian speed*. Formula 7.2 shows the calculation.

$$s_{rec,zebra} = \frac{v_c}{3,6} \cdot t_r + \left(\frac{v_c}{3,6}\right)^2 \cdot \frac{1}{2 \cdot d_s} + l_b \tag{7.1}$$

$$s_{rec,regular} = \frac{v_c}{3,6} \cdot \frac{w}{v_p} \tag{7.2}$$

| | |
|---|---|
| $s_{rec}$ | recommended sight distance $[m]$ |
| $d_s$ | car deceleration, stopping: $[m/s^2]$ |
| $l_b$ | length of the bonnet, distance from car driver to car front $[m]$ |
| $t_r$ | car driver's reaction time: $[s]$ |
| $v_c$ | driven car speed $v_{85}$ $[km/h]$ |
| $v_p$ | pedestrian walking speed: $[m/s]$ |
| $w$ | crossing width: waiting position to end of lane (left side) or opposite curb (right side) $[m]$ |

The use of a factor to model different stopping distances for different longitudinal gradients could refine the result, but is not seen as necessary.

In Austria the calculation of the sight distance at regular crossings contains a term of a slight car deceleration (1,0 $m/s^2$). This term is also seen as optional.

At regular crossings no pedestrian reaction time is included in the recommendation. Reason for that is, that on the one hand it is not the left front edge of the car (what would technically be necessary) but the middle of the car front, which is defined as the point that has to be seen. On the other hand, if a pedestrian takes one step out at the street and then recognises an approaching vehicle, he will be able to step back at the curb safely, before the vehicle arrives.

If the sight distances cannot be achieved by widening the curb, free space next to the extension shall be created, for example by planting trees.

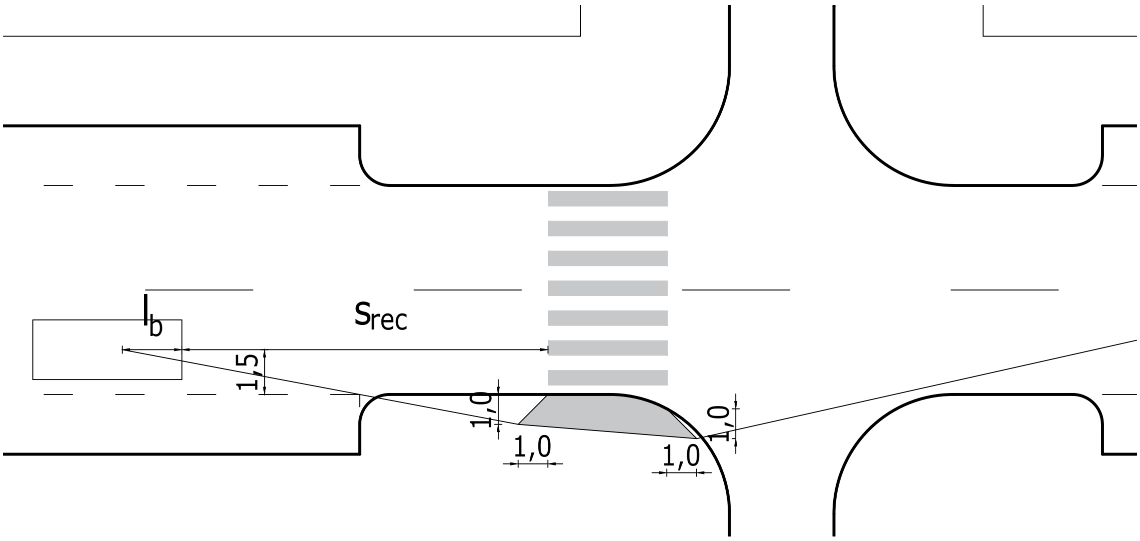


Figure 7.2: Recommended sight distances at zebra crossings

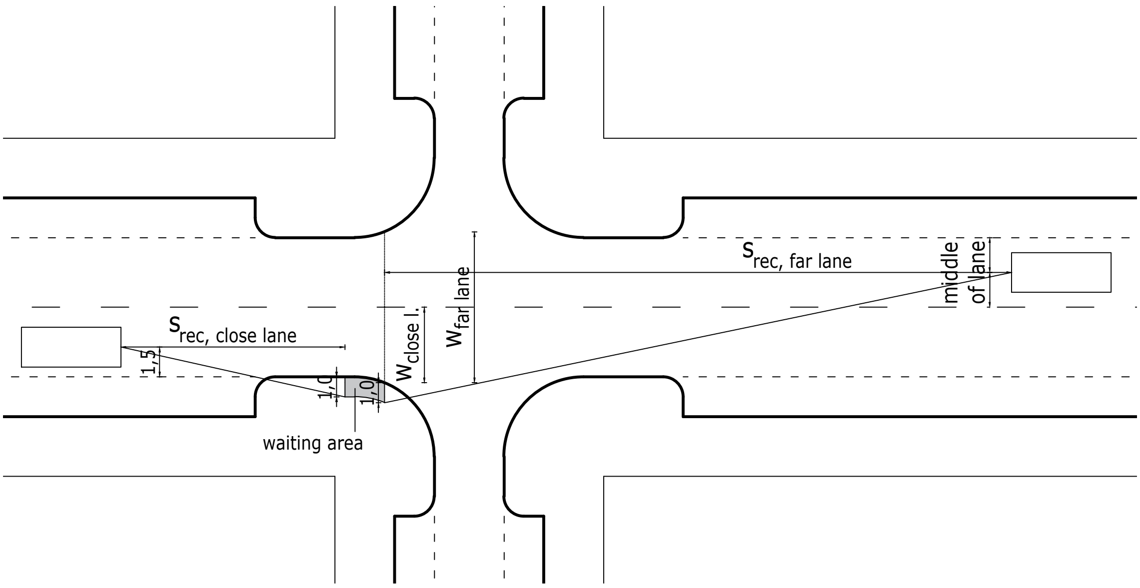


Figure 7.3: Recommended sight distances at regular crossings

Table 7.1: Comparison of different national guidelines and recommendations, zebra crossings. Definitions of measures can be seen in figure 4.8

| Nr | | Unit | AUT | GER | SUI | Recomm. |
|---|---|---|---|---|---|---|
| 1 | Position of waiting pedestrian | m | 1,0 | 1,0 | 1,0 | 1,0** |
| 2 | | | Middle of crossing | middle of crossing | Defined Waiting area | Defined Waiting area |
| 3 | Position of driver | m | not defined | not defined | middle of lane | 1,5 m from parking lane |
| 4 | Minimum length with no parking | m | 3 | 5/8/12* | not defined | not defined |
| 5 | Sight distance | | | | | no recom- |
| | 30 km/h | m | 20 | 15 | 25 | mendation, |
| | 40 km/h | m | 30 | 25 | 40 | formulas |
| | 50 km/h | m | 45 | 35 | 55 | provided |
| | Vertical vision range | m | 0,6 - 2,5 | not defined | 0,6 - 2,5 | 0,6 - 2,5 |
| 6 | Curb extension width | | 20 cm less than width of parking lane | 30 ... 70 cm more than parking lane | 0 ... 20 cm more than parking lane | ≥ parking lane's width |

* for 30/40/50 km/h. If the extension reaches out more than 30 cm in front of the parking lane, 5 m can be applied at all speeds

** May be extended at highly frequented crosswalks according to table 6.1

Table 7.2: Comparison of different national guidelines and recommendations, regular crossings. Definitions of measures can be seen in figure 4.8

| Nr | | Unit | AUT | GER | SUI | **Recomm.** |
|---|---|---|---|---|---|---|
| 1 | Position of waiting pedestrian | m | 0,2 | close to the curb | 1,0 | 1,0 |
| 2 | | | Middle of crossing | middle of crossing | Width of markings | In front of curb ramp |
| 3 | Position of car | m | not defined | not defined | middle of lane | 1,5 m from parking lane |
| 4 | Minimum length with no parking | m | 5,5 | 5/8/12* | not defined | not defined |
| 5 | Sight distance | | | | | no recom-mendation, formulas provided |
| | 30 km/h | m | 25/50** | 30 | 25 | |
| | 40 km/h | m | 34/68** | 35 | 25 | |
| | 50 km/h | m | 43/86** | 50 | 25/35*** | |
| | Vertical vision range | m | 0,6 - 2,5 | not defined | 0,6 - 2,5 | 0,6 - 2,5 |
| 6 | Curb extension width | | 20 cm less than width of parking lane | 30 ... 70 cm more than parking lane | 0 ... 20 cm more than parking lane | $\geq$ parking lane's width |

* for 30/40/50 km/h. If the extension reaches out more than 30 cm in front of the parking lane, half of the marked crossing width is enough

** Left/right for a 6,5 m street width

*** Local streets/collecting streets

# List of Tables

# List of Figures

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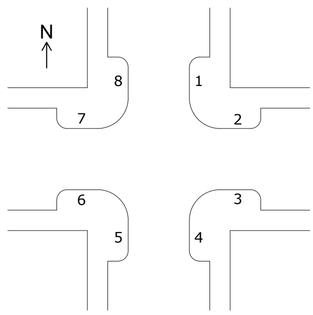
# Appendix A

# List of investigated curb extensions

**Legend**

| | |
|---|---|
| Intersection | All intersections are located in Vienna. |
| Intersection nr. | A number for better identification was assigned to each intersection. |
| Extension nr. | The curb extensions were numbered clockwise, starting at the north-eastern corner. At streets with two way service, the extensions nr. 1,3,5 and 7 have approaching cars at the opposite lane from right. At extensions with the numbers 2,4,6 and 8 cars are approaching from left at the adjacent lane. |
| Zebra / | 1: Zebra crossing |
| non zebra | 0: Regular crossing |
| Car speed | The measured or estimated $v_{85}$ speed of approaching vehicles. |
| Lane use | PP Parallel parking |
| | P45 Diagonal Parking lane, 45° |
| | P60 Diagonal Parking lane, 60° |
| | P90 Rectangular parking lane |
| | BikeP Bicycle parking |



| | |
|---|---|
| SLO type | P Parked car<br>PB Parked bicycle<br>VENT Ventilation shaft<br>BIN Dustbin<br>- No sight limiting objects |
| SLO distance side | Distance from walking line to the sight limiting object. |
| SLO distance forward | Distance from the curb to the sight limiting object. Positive values are used for sight limiting objects in front of the curb. If the sight limiting object is behind the curb (but in front of the waiting pedestrian), negative values were used. |
| Distance to middle of lane | Distance from the curb to the middle of the lane. For zebra crossings the driver is assumed to be in the middle of the lane. At regular crossings the point where the vehicle will be recognised is also in the middle of the lane. |
| Crossing width non zebra | Curb to curb distance for extensions with uneven numbers, width of the adjacent lane for even numbers. The 0,2 m at the curb (from the waiting position) are not included because the RVS defines it that way. |
| Required sight distance | Distance to guarantee a complete stop in front of a zebra crossing or enough time to cross before the car reaches a regular crossing. Calculation as shown above. |
| Actual sight distance | Calculation as shown above |
| RVS compliant | OK if the actual sight distance is the same or bigger than the required, otherwise NOT OK. |
| Extension width | Maximum width of the curb extension. Those values were not used in the calculation. |
| Offset through turning radius | At curb extensions at intersections sometimes the walking line doesn't cross the curb at the furthest point. The offset resulting from those turning radii is included in column *SLO distance forward* and additionally provided here. |

| intersection nr. | extension nr. | zebra / non zebra | car speed | lane use | SLO type | SLO distance side | SLO distance forward | distance to middle of lane | Crossing width non zebra | required sight distance | actual sight distance | RVS compliant | speed for safe crossing | if offset = 0, then | necessary SLO move side | 0 Offset, necessary SLO move | extension width | offset by turning radius |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 / 0 | km/h | | | m | m | m | m | m | m | | km/h | | m | m | m | m |
| 01 | 1 | 1 | 36 | P45 | P | 3,20 | 0,40 | 2,50 | | 26,3 | 8,0 | NOT OK | 15,8 | NOT OK | 7,3 | 5,3 | 3,80 | 0,00 |
| 01 | 2 | 1 | 38 | P45 | P | 2,60 | 0,60 | 1,77 | | 28,6 | 4,5 | NOT OK | 10,1 | NOT OK | 13,9 | 10,6 | 3,80 | 0,00 |
| 01 | 3 | 1 | 38 | PP | P | 1,16 | 0,37 | 3,87 | | 28,6 | 4,1 | NOT OK | 9,4 | NOT OK | 6,9 | 5,2 | 1,80 | 0,02 |
| 01 | 6 | 1 | 38 | PP | P | 1,58 | 0,27 | 1,47 | | 28,6 | 3,1 | NOT OK | 7,4 | NOT OK | 13,1 | 11,4 | 1,80 | 0,07 |
| 01 | 7 | 1 | 38 | P45 | P | 0,80 | 0,46 | 4,06 | | 28,6 | 2,8 | NOT OK | 6,8 | NOT OK | 7,4 | 5,4 | 3,88 | 0,11 |
| 01 | 8 | 1 | 36 | PP | P | 2,22 | 0,35 | 2,45 | | 26,3 | 5,7 | NOT OK | 12,1 | NOT OK | 8,1 | 6,3 | 1,80 | 0,00 |
| 02 | 2 | 0 | 43 | PP | P | 11,50 | 0,58 | 2,41 | 4,24 | 41,7 | 38,5 | NOT OK | 40,3 | OK | 0,9 | | 1,92 | 0,00 |
| 02 | 3 | 0 | 43 | PP | P | 5,20 | 0,76 | 5,89 | 8,30 | 64,7 | 33,0 | NOT OK | 29,2 | OK | 5,0 | | 1,75 | 0,00 |
| 02 | 6 | 0 | 43 | PP | P | 4,80 | 1,77 | 3,43 | 5,09 | 47,8 | 8,8 | NOT OK | 15,4 | NOT OK | 21,2 | 0,3 | 1,45 | 0,73 |
| 02 | 7 | 0 | 43 | PP | P | 11,50 | 0,58 | 5,90 | 8,60 | 65,7 | 89,9 | OK | | | | | 1,92 | 0,00 |
| 03 | 1 | 0 | 38 | P45 | - | 5,53 | 0,00 | 2,18 | 4,80 | 39,1 | 65,7 | OK | | | | | 2,72 | 0,00 |
| 03 | 2 | 0 | 38 | P90 | P | 6,21 | 0,85 | 2,19 | 3,53 | 31,0 | 14,1 | NOT OK | 20,8 | OK | 7,4 | | 4,50 | 0,45 |
| 03 | 3 | 0 | 38 | PP | P | 6,70 | 0,25 | 4,26 | 6,00 | 45,3 | 66,4 | OK | | | | | 1,80 | 0,00 |
| 03 | 6 | 0 | 38 | PP | P | 5,91 | 0,25 | 1,59 | 2,92 | 26,6 | 23,4 | NOT OK | 34,2 | OK | 0,8 | | 1,80 | 0,00 |
| 03 | 7 | 0 | 38 | P90 | P | 6,24 | 1,36 | 5,38 | 6,96 | 49,2 | 22,3 | NOT OK | 24,1 | OK | 7,5 | | 4,50 | 0,96 |
| 04 | 1 | 0 | 38 | P45 | P | 7,57 | 3,01 | 5,85 | 7,67 | 51,5 | 14,3 | NOT OK | 20,5 | OK | 19,8 | | 1,20 | 0,09 |
| 04 | 2 | 0 | 38 | P90 | P | 2,52 | 0,78 | 2,53 | 4,28 | 36,0 | 7,0 | NOT OK | 13,6 | NOT OK | 10,4 | 1,2 | 3,00 | 0,78 |
| 04 | 3 | 0 | 38 | P60 | P | 4,95 | 0,07 | 5,32 | 7,07 | 49,6 | 101,2 | OK | | | | | 4,00 | 0,07 |
| 04 | 4 | 0 | 38 | PP | P | 1,60 | 0,70 | 2,33 | 3,86 | 33,3 | 4,5 | NOT OK | 11,1 | NOT OK | 10,2 | 2,2 | 1,20 | 0,00 |
| 04 | 5 | 0 | 38 | PP | P | 7,80 | 0,80 | 5,59 | 7,92 | 52,2 | 45,2 | NOT OK | 34,8 | OK | 1,2 | | 1,20 | 0,00 |
| 04 | 6 | 0 | 38 | PP | P | 10,24 | 1,26 | 2,60 | 3,94 | 33,8 | 19,6 | NOT OK | 25,0 | OK | 7,4 | | 1,80 | 1,01 |
| 04 | 7 | 0 | 38 | PP | P | 5,59 | 0,40 | 4,42 | 6,01 | 45,4 | 43,0 | NOT OK | 36,6 | OK | 0,3 | | 4,50 | 0,00 |
| 04 | 8 | 0 | 38 | PP | P | 4,08 | 0,80 | 1,82 | 2,84 | 25,9 | 8,2 | NOT OK | 15,6 | NOT OK | 8,8 | 0,2 | 1,27 | 0,00 |

| intersection nr. | extension nr. | zebra / non zebra | car speed | lane use | SLO type | SLO distance side | SLO distance forward | distance to middle of lane | Crossing width non zebra | required sight distance | actual sight distance | RVS compliant | speed for safe crossing | if offset = 0, then | necessary SLO move side | 0 Offset, necessary SLO move | extension width | offset by turning radius |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 / 0 | km/h | | | m | m | m | m | m | m | | km/h | | m | m | m | m |
| 05 | 1 | 0 | 38 | P45 | P | 5,83 | 0,90 | 4,50 | 5,20 | 41,4 | 24,9 | NOT OK | 26,6 | OK | 3,9 | | 3,40 | 0,00 |
| 05 | 2 | 0 | 38 | P90 | P | 1,87 | 0,75 | 2,13 | 3,50 | 30,8 | 4,6 | NOT OK | 11,0 | NOT OK | 10,7 | 2,0 | 3,50 | 0,00 |
| 05 | 3 | 0 | 38 | P90 | P | 1,46 | 0,75 | 4,88 | 7,00 | 49,4 | 7,8 | NOT OK | 16,6 | NOT OK | 7,8 | 0,8 | 3,50 | 0,00 |
| 05 | 4 | 0 | 38 | PP | P | 1,16 | 0,20 | 1,79 | 3,38 | 30,0 | 5,8 | NOT OK | 12,2 | NOT OK | 4,9 | 2,2 | 1,80 | 0,00 |
| 05 | 6 | 0 | 38 | P60 | P | 9,30 | 2,13 | 3,51 | 4,88 | 39,6 | 14,8 | NOT OK | 19,7 | OK | 15,6 | | 4,00 | 1,88 |
| 05 | 7 | 0 | 38 | P45 | P | 0,30 | 1,29 | 5,42 | 7,04 | 49,5 | 1,1 | NOT OK | 13,3 | NOT OK | 12,8 | 2,0 | 3,10 | 0,14 |
| 05 | 8 | 0 | 38 | PP | P | 1,59 | 0,15 | 0,70 | 1,25 | 12,4 | 4,1 | NOT OK | 14,0 | NOT OK | 3,2 | 1,7 | 1,95 | 0,00 |
| 06 | 1 | 0 | 38 | PP | P | 2,97 | 0,70 | 4,30 | 5,90 | 44,9 | 14,9 | NOT OK | 19,7 | OK | 6,0 | | 1,50 | 0,00 |
| 06 | 2 | 0 | 38 | P90 | P | 6,40 | 1,30 | 2,59 | 3,87 | 33,4 | 11,9 | NOT OK | 18,0 | OK | 11,6 | | 4,00 | 1,05 |
| 06 | 3 | 0 | 38 | P90 | P | 4,31 | 0,73 | 4,60 | 6,13 | 45,9 | 22,2 | NOT OK | 24,1 | OK | 4,6 | | 3,60 | 0,13 |
| 06 | 4 | 0 | 38 | P45 | P | 7,57 | 1,23 | 2,93 | 4,63 | 38,2 | 16,6 | NOT OK | 21,2 | OK | 9,9 | | 3,20 | 0,13 |
| 06 | 5 | 0 | 38 | PP | P | 1,47 | 0,50 | 3,20 | 6,00 | 45,3 | 7,1 | NOT OK | 15,1 | NOT OK | 7,9 | 1,7 | 1,60 | 0,00 |
| 06 | 6 | 0 | 38 | P90 | P | 11,54 | 0,93 | 2,24 | 3,55 | 31,2 | 24,9 | NOT OK | 31,7 | OK | 2,9 | | 4,00 | 0,68 |
| 06 | 7 | 0 | 38 | P90 | P | 5,53 | 0,65 | 4,59 | 6,15 | 46,0 | 31,2 | NOT OK | 29,3 | OK | 2,6 | | 3,80 | 0,15 |
| 06 | 8 | 0 | 38 | P45 | P | 3,86 | 1,20 | 1,70 | 2,20 | 20,8 | 5,2 | NOT OK | 12,5 | NOT OK | 11,5 | 2,1 | 3,20 | 0,10 |
| 07 | 1 | 1 | 38 | PP | P | 2,60 | 0,70 | 5,00 | | 28,6 | 9,2 | NOT OK | 17,5 | NOT OK | 5,5 | 2,8 | 1,50 | 0,20 |
| 07 | 2 | 1 | 38 | P90 | P | 20,34 | 1,10 | 2,60 | | 28,6 | 34,9 | OK | | | | | 3,80 | 1,10 |
| 07 | 3 | 1 | 38 | P90 | P | 4,74 | 0,88 | 5,18 | | 28,6 | 15,6 | NOT OK | 25,4 | NOT OK | 4,0 | 0,7 | 3,80 | 0,48 |
| 07 | 4 | 1 | 38 | P45 | P | 7,90 | 0,60 | 1,70 | | 28,6 | 13,3 | NOT OK | 22,8 | NOT OK | 9,0 | 5,7 | 3,70 | 0,00 |
| 07 | 5 | 1 | 38 | PP | P | 2,27 | 0,60 | 3,90 | | 28,6 | 7,0 | NOT OK | 14,2 | NOT OK | 7,1 | 4,4 | 1,50 | 0,10 |
| 07 | 6 | 1 | 38 | PP | P | 1,88 | 0,35 | 1,85 | | 28,6 | 4,0 | NOT OK | 9,1 | NOT OK | 11,7 | 9,6 | 1,80 | 0,00 |
| 07 | 7 | 1 | 38 | P45 | P | 12,00 | 3,40 | 6,85 | | 28,6 | 21,4 | NOT OK | 31,5 | OK | 4,0 | | 0,90 | 0,00 |
| 07 | 8 | 1 | 25 | P90 | VENT | 1,90 | -0,60 | 0,50 | | 15,2 | 7,1 | NOT OK | 14,5 | NOT OK | 2,2 | 8,2 | 4,80 | 0,00 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| offset by turning radius | m | 0,30 | 1,00 | 0,30 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 1,10 | 1,00 | 0,70 | 1,10 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,54 | 0,50 | 0,30 | 0,00 | 0,00 |
| extension width | m | 1,80 | 3,80 | 1,80 | 1,80 | 1,80 | 1,80 | 3,80 | 1,80 | 2,65 | 1,80 | 4,40 | 1,80 | 4,00 | 4,00 | 1,80 | 1,80 | 1,80 | 2,50 | 2,25 | 3,85 | 1,90 | 1,70 | 1,80 | 1,50 | 1,50 | 1,50 | 1,50 |
| 0 Offset, necessary SLO move | m | | | | | | | | | | 3,5 | | | | | 3,4 | 0,9 | 2,2 | | | | | 2,2 | | | 5,5 | 5,8 | 9,0 |
| necessary SLO move side | m | 2,5 | 13,1 | 2,8 | 0,3 | 1,2 | 2,0 | 3,0 | 0,8 | | 4,6 | 3,8 | | | 2,6 | 13,5 | 10,9 | 10,9 | | | | | 5,3 | 5,2 | 4,7 | 8,5 | 7,8 | 13,9 |
| if offset = 0, then | | OK | OK | OK | OK | OK | OK | OK | OK | | NOT OK | OK | | | OK | NOT OK | NOT OK | NOT OK | | | | | NOT OK | OK | OK | NOT OK | NOT OK | NOT OK |
| speed for safe crossing | km/h | 35,0 | 17,2 | 27,3 | 43,2 | 36,7 | 26,8 | 25,7 | 40,6 | | 24,5 | 19,1 | | | 19,9 | 18,4 | 24,6 | 16,3 | | | | | 16,1 | 27,6 | 31,4 | 9,2 | 8,7 | 19,0 |
| RVS compliant | | NOT OK | NOT OK | NOT OK | NOT OK | NOT OK | NOT OK | NOT OK | NOT OK | OK | NOT OK | NOT OK | OK | OK | NOT OK | NOT OK | NOT OK | NOT OK | OK | OK | OK | OK | NOT OK | NOT OK | NOT OK | NOT OK | NOT OK | NOT OK |
| actual sight distance | m | 44,4 | 11,0 | 27,0 | 35,9 | 46,8 | 15,7 | 24,0 | 33,3 | 90,1 | 14,8 | 13,5 | 29,2 | 18,9 | 14,4 | 0,0 | 17,3 | 4,8 | 209,2 | ? | 18,4 | 20,3 | 9,9 | 26,8 | 21,4 | 4,0 | 3,7 | 10,3 |
| required sight distance | m | 64,6 | 33,1 | 43,7 | 37,6 | 63,0 | 23,5 | 42,2 | 37,6 | 37,3 | 37,3 | 20,3 | 24,1 | 18,5 | 24,1 | 92,5 | 92,9 | 80,1 | 45,1 | 68,1 | 17,0 | 17,0 | 45,1 | 69,3 | 34,7 | 20,9 | 20,9 | 34,7 |
| Crossing width non zebra | m | 7,30 | 3,83 | 5,66 | 3,50 | 7,00 | 2,53 | 5,36 | 3,50 | | | 4,20 | 7,00 | 3,60 | 6,90 | 10,20 | 10,30 | 7,80 | 4,70 | 9,40 | | | 4,70 | 9,94 | | | | |
| distance to middle of lane | m | 5,45 | 2,67 | 4,00 | 1,85 | 5,15 | 1,37 | 4,00 | 1,85 | 1,58 | 4,93 | 2,85 | 5,25 | 2,25 | 5,35 | 5,95 | 6,25 | 6,25 | 2,35 | 7,05 | 2,35 | 2,30 | 2,45 | 7,49 | 4,70 | 2,60 | 2,30 | 1,63 |
| SLO distance forward | m | 0,50 | 1,50 | 0,50 | 0,20 | 0,20 | 0,20 | 0,50 | 0,20 | 0,20 | 0,20 | 1,50 | 1,20 | 0,90 | 1,30 | 0,70 | 0,70 | 0,70 | 0,00 | -0,30 | 0,35 | 0,30 | 0,20 | 0,74 | 1,00 | 0,80 | 0,50 | 0,50 |
| SLO distance side | m | 5,50 | 6,50 | 4,50 | 7,00 | 3,50 | 4,00 | 4,00 | 6,50 | 42,00 | 3,00 | 7,50 | 7,50 | 8,50 | 3,90 | 0,00 | 2,50 | 0,70 | 16,41 | 12,88 | 7,40 | 8,00 | 1,50 | 3,27 | 7,50 | 2,00 | 1,70 | 5,90 |
| SLO type | | P | P | P | P | P | P | P | P | P | P | P | P | P | P | P | P | P | - | P | P | P | PB | P | P | P | P | P |
| lane use | | PP | P45 | PP | PP | PP | PP | P45 | PP | PP | PP | P90 | PP | P45 | P45 | PP | PP | PP | PP | PP | P45 | PP | BikeP | PP | PP | PP | PP | PP |
| car speed | km/h | 45 | 38 | 38 | 45 | 45 | 38 | 38 | 45 | 45 | 45 | 25 | 25 | 25 | 25 | 51 | 51 | 51 | 43 | 43 | 27 | 27 | 43 | 43 | 43 | 31 | 31 | 43 |
| zebra / non zebra | 1 / 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| extension nr. | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 4 | 5 | 2 | 3 | 6 | 7 | 1 | 3 | 7 | 2 | 3 | 4 | 5 | 6 | 7 | 5 | 6 | 7 | 8 |
| intersection nr. | | 08 | 08 | 08 | 08 | 08 | 08 | 08 | 08 | 09 | 09 | 09 | 09 | 09 | 09 | 10 | 11 | 11 | 12 | 12 | 12 | 12 | 12 | 12 | 13 | 13 | 13 | 13 |

| intersection nr. | extension nr. | zebra / non zebra | car speed | lane use | SLO type | SLO distance side | SLO distance forward | distance to middle of lane | Crossing width non zebra | required sight distance | actual sight distance | RVS compliant | speed for safe crossing | if offset = 0, then | necessary SLO move side | 0 Offset, necessary SLO move | extension width | offset by turning radius |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 / 0 | km/h | | | m | m | m | m | m | m | | km/h | | m | m | m | m |
| 14 | 1 | 0 | 25 | P45 | P | 3,40 | 0,10 | 3,00 | 4,65 | 21,5 | 36,3 | OK | | | | | 4,00 | 0,00 |
| 14 | 2 | 0 | 31 | P45 | P | 4,60 | 0,30 | 2,40 | 4,50 | 28,6 | 23,9 | NOT OK | 27,2 | OK | 0,9 | | 4,00 | 0,00 |
| 14 | 3 | 0 | 31 | P90 | P | 6,10 | 0,80 | 4,10 | 6,50 | 34,8 | 26,2 | NOT OK | 26,2 | OK | 2,0 | | 3,60 | 0,00 |
| 14 | 6 | 0 | 31 | P90 | P | 4,50 | 0,80 | 1,40 | 2,00 | 15,2 | 7,2 | NOT OK | 16,6 | OK | 5,0 | | 3,50 | 0,00 |
| 14 | 8 | 0 | 25 | PP | P | 1,45 | 0,60 | 1,65 | 2,60 | 14,7 | 3,4 | NOT OK | 9,3 | NOT OK | 4,9 | 1,1 | 1,80 | 0,00 |
| 15 | 6 | 1 | 31 | PP | P | 4,07 | 0,40 | 1,93 | | 20,9 | 8,5 | NOT OK | 16,5 | NOT OK | 5,9 | 4,2 | 1,55 | 0,00 |
| 15 | 7 | 1 | 31 | PP | P | 9,27 | 0,20 | 4,78 | | 20,9 | 44,6 | OK | | | | | 1,80 | 0,00 |
| 16 | 2 | 1 | 38 | PP | P | 4,36 | 0,99 | 2,49 | | 28,6 | 7,6 | NOT OK | 15,2 | NOT OK | 11,9 | 7,1 | 1,80 | 0,79 |
| 16 | 3 | 1 | 38 | PP | P | 5,15 | -0,30 | 3,30 | | 28,6 | 31,6 | OK | | | | | 2,30 | 0,00 |
| 16 | 4 | 1 | 38 | PP | P | 4,73 | 0,20 | 2,83 | | 28,6 | 15,1 | NOT OK | 24,8 | NOT OK | 4,2 | 3,2 | 1,80 | 0,00 |
| 16 | 5 | 1 | 38 | PP | P | 4,59 | 0,30 | 2,93 | | 28,6 | 13,9 | NOT OK | 23,4 | NOT OK | 4,9 | 3,3 | 1,80 | 0,00 |
| 16 | 6 | 1 | 38 | PP | P | 6,90 | 0,25 | 1,75 | | 28,6 | 15,2 | NOT OK | 25,0 | NOT OK | 6,1 | 4,5 | 1,75 | 0,00 |
| 16 | 7 | 1 | 38 | PP | P | 5,60 | 0,20 | 4,65 | | 28,6 | 26,4 | NOT OK | 36,1 | OK | 0,5 | | 1,80 | 0,00 |
| 17 | 1 | 0 | 36 | PP | P | 3,50 | 0,20 | 4,40 | 5,80 | 41,2 | 40,3 | NOT OK | 35,4 | OK | 0,1 | | 2,42 | 0,00 |
| 17 | 2 | 0 | 51 | PP | P | 4,47 | 0,87 | 3,19 | 5,01 | 58,4 | 14,2 | NOT OK | 19,2 | NOT OK | 14,0 | 1,3 | 1,80 | 0,67 |
| 17 | 7 | 0 | 51 | PP | P | 2,18 | 0,94 | 6,89 | 11,00 | 95,3 | 13,5 | NOT OK | 24,2 | NOT OK | 13,2 | 1,2 | 1,80 | 0,74 |
| 17 | 8 | 0 | 36 | PP | P | 3,38 | 0,00 | 1,40 | 2,80 | 24,1 | 27,0 | OK | | | | | 2,50 | 0,00 |
| 18 | 2 | 1 | 30 | PP | BIN | 1,62 | -0,23 | 2,00 | | 19,9 | 6,3 | NOT OK | 13,2 | NOT OK | 3,5 | 6,3 | 1,50 | 0,00 |
| 18 | 3 | 1 | 30 | P45 | P | 10,33 | 3,39 | 6,19 | | 19,9 | 16,9 | NOT OK | 26,9 | OK | 1,8 | | 3,80 | 2,99 |
| 19 | 2 | 0 | 30 | PP | P | 6,40 | 1,00 | 2,75 | 4,50 | 27,4 | 15,7 | NOT OK | 20,7 | OK | 4,7 | | 1,80 | 0,30 |
| 19 | 3 | 0 | 30 | P45 | P | 7,80 | 0,15 | 1,90 | 4,35 | 26,8 | 46,8 | OK | | | | | 4,50 | 0,15 |
| 19 | 4 | 0 | 27 | PP | P | 1,00 | 0,00 | 1,90 | 3,80 | 21,3 | 10,5 | NOT OK | 16,8 | NOT OK | 1,0 | 1,0 | 2,00 | 0,00 |
| 19 | 5 | 0 | 27 | PP | P | 2,20 | 0,35 | 2,25 | 4,15 | 22,5 | 9,8 | NOT OK | 16,0 | OK | 2,9 | | 1,80 | 0,15 |
| 20 | 3 | 0 | 51 | PP | P | 7,50 | 0,00 | 5,05 | 9,20 | 88,0 | 196,9 | OK | | | | | 2,00 | 0,00 |
| 21 | 4 | 1 | 33 | PP | P | 1,70 | 0,00 | 1,63 | | 23,0 | 4,5 | NOT OK | 10,0 | NOT OK | 7,1 | 7,1 | 1,90 | 0,00 |
| 21 | 5 | 1 | 33 | PP | BIN | 0,80 | 0,50 | 5,88 | | 23,0 | 3,7 | NOT OK | 8,6 | NOT OK | 4,2 | 3,1 | 1,90 | 1,00 |
| 22 | 7 | 0 | 38 | PP | P | 2,00 | 0,00 | 4,88 | 6,50 | 47,5 | 50,8 | OK | | | | | 2,00 | 0,00 |