CHALMERS

Bicycle Priority Street

- The Missing Link in the Safe and Sustainable Infrastructure

Master of Science Thesis in the Master's Program Infrastructure and Environmental Engineering

HELENA DENVALL
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Department of Civil and Environmental Engineering
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CHALMERS UNIVERSITY OF TECHNOLOGY
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ABSTRACT

Bicycle traffic has many positive outcomes. It is a sustainable transportation mode for several reasons such as no contribution to neither noise nor emissions, not demanding much space and it is also efficient regarding energy demands. But it is also a vulnerable and unprotected vehicle. To create a safe traffic environment, the Swedish government has developed the Vision Zero, a vision in traffic safety of an infrastructure with no severe or fatal accidents. To develop the traffic safety for bicyclists, the research of innovative solutions for the bicyclist infrastructure must be conducted and implemented.

In several countries a so called Bicycle Priority Street is used in order to remove missing links in the bicycle network where the urban space is too dense to implement bicycle paths. A Bicycle Priority Street is an integrated infrastructure solution where the motorized vehicles are allowed on the permissions of the bicycles. It also increases the availability and attractiveness for the bicyclists and is an essential component for creating an infrastructure aimed for the bicyclists.

This thesis investigates if an implementation of a Bicycle Priority Street in Sweden improves the traffic safety and contributes to reach the goal in Vision Zero, and also evaluates the potential and effects it has on the infrastructure. The report concludes with a recommendation of three different street plans of a Bicycle Priority Street. These have positive effects on the character of the streets and influence the modal split while the effects regarding environment and subjective safety/security are remained on the same level as before an implementation. To have more bicycles than motorized vehicles on the Bicycle Priority Street is essential since it ensures that the road is used on the permissions and conditions of the bicycles. A speed limit of either 30 km/h, 20 km/h or as bicycle speed is recommended. The speed level affects which kind of bicyclists that will appreciate the Bicycle Priority Street, the commuters, social bicyclists and to some extent fitness bicyclists gain the most while elderly and children are not suitable and do not appreciate the Bicycle Priority Street.

Several factors that influence the traffic safety are impacted when implementing a Bicycle Priority Street. Giving priority to the bicyclists in intersections increases the probability of a severe or fatal accident, but most of the factors are positive and contribute to an improvement in traffic safety. Hence, to create a street that increase the availability and attractiveness for the bicyclists is an essential component in creating a sustainable urban space. The quality and character of the street is increased. The Bicycle Priority Street is dimensioned for the bicycles which improves the traffic safety.

Key words: Bicycle Priority Street, shared space, bicycle infrastructure, traffic safety, bicycle street, cykelfartsgata

Contents

Preface

This Master's Thesis has been carried out from January 2013 to June 2013, at the master's program Infrastructure and Environmental Engineering at the Division of GeoEngineering, Road and Traffic Research Group at Chalmers University of Technology, Sweden. The thesis has been supervised by Gunnar Lanner.

This thesis has been carried out at Sweco Infrastructure, Gothenburg, with supervision of Roger Johansson and Cecilia Wideman.

Thank you to everyone who has helped us with this report. Several persons have made this thesis possible:

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Gothenburg, June 2013

Helena Denvall & Sofie Johansson

Vocabulary

Accessibility	The capability of reaching a required location.
Availability	The ease and speed of reaching a required location.
Bicycle lane	A lane designed for the bicycle traffic on a street (SKL, 2010).
Bicycle path	Road/part of a road that is intended to contain the cyclist and mopeds (SKL, 2010).
ISS	Injury Severity Score. A calculation of the severity of a person's injuries on a person used by the hospitals in STRADA (Transportstyrelsen, 2012). In STRADA the ISS scores are translated to the severities; • ISS score 0 means no injury • ISS score 1-8 means minor injury • ISS score 9- means severe injury
Minor injury	An injury that is not severe (Transportstyrelsen, 2013).
Mixed traffic	When different road users share the same space (SKL, 2010).
PCU	Passenger Car Unit, a measure where the different traffic modes get a unit in cars. Trucks, which are longer than cars, might be two PCU depending on the one who sets the PCU. This measure is used in the Netherlands regarding intensities on the Bicycle Priority Street. Since the motorized traffic almost only consists of cars it is in this report used as AADT (Annual Average Daily Traffic).
Pedestrian street	Road only for pedestrians. Transportation by other means, except for freight, residents, handicapped persons or hotel guests are forbidden. Bicycles are permitted if driving in the same speed as the pedestrians (SKL, 2010).
Pictogram	A symbol that represents a concept by a simplified picture. In this report it refers to the road pictures on the ground explaining the concept of the road.
Safety	If nothing else is mentioned in the text the report aims at objective safety/ actual safety when writing safety.
Severe injury	Injuries such as fractures, serious cut injuries and concussions that are expected to make the injured person hospitalized (Transportstyrelsen, 2013).
Speed level	The actual speed the motorized vehicles keep on a road.
STRADA	Swedish Traffic Accident Data Acquisition, a national information system on injuries and accidents in the entire road transport system with reports from both police and hospitals (Transportstyrelsen, 2012).
Subjective safety/Security	The safety the road user experience.
Traffic calming	Reduces the negative effects of the motorized vehicle. Changes the speed, flow, the modal split and contributes to a nicer environment (SKL, 2009).

1 Introduction

To create a safe traffic environment the Swedish government has developed the Vision Zero, a vision in traffic safety of an infrastructure with no severe or fatal accidents. It is both an ethical and strategic approach where the infrastructure should develop into a system more adjusted to the humans and our probability to make errors (Trafikverket, 2012a). Even if an accident does occur, the consequences should not lead to severe or fatal injuries. To reach this goal in Vision Zero, intermediate targets were set up in 2009 (Trafikverket, 2012b). The current goal is to halve the fatal accidents and reduce the severe injured, reported by the police, by 25 percent from 2007 to 2020 (Trafikverket, 2013). To reach the goal of reducing severe accidents, improving the traffic safety for bicyclists is the most significant road user to work with.

It is important to notice that an increased amount of bicyclists should still be aimed. Bicycle traffic has many positive consequences such as improved health, it is a cheap type of transportation, the trip does not contribute to pollutions and it does not demand as much space as cars, both in parking and on the roads (Boverket et al., 2004). It does however have negative qualities as well since it is a vulnerable and unprotected vehicle, exposed for accidents and pollutions. To develop the traffic safety for bicyclists the operation and maintenance needs to be improved and more research of innovative solutions in traffic safety needs to be conducted and implemented.

It has for a long period been common among the Swedish municipalities to develop the infrastructure for the motorized vehicles, sometimes at the expense of other road users. Today however, creating an infrastructure adjusted for bicycles is getting more required and acceptable by the citizen and politicians. The bicycle networks today have many missing links where the bicycles are either forced to drive in mixed traffic or to take detours. As the cities today are dense, and often strive to become even more so, solutions in the infrastructure for increasing the availability but at the same time not demand much space are required. Often there is no space for inserting a bicycle path. A solution to create a safe environment for all type of road users in the dense city is therefore required.

In several countries a so called Bicycle Priority Street is used in order to remove missing links in the bicycle network where the urban space is too dense to implement bicycle paths. A Bicycle Priority Street is a bicycle street where the motorized vehicles are allowed on the permissions of the bicycles. It also increases the availability and attractiveness for the bicyclists. In Germany this type of bicycle infrastructure is called *Fahrradstrasse* and in the Netherlands *Fietsstraat*, which both mean bicycle street in English. In Sweden it is called *Cykelfartsgata*, bicycle speed street. In this master thesis this type of bicycle infrastructure is named Bicycle Priority Street. This is not yet a known name in the business but is considered applicable since it explains the concept of the street. In Sweden Bicycle Priority Street is used in Linköping and is today discussed as a new type of street among many other Swedish municipalities. The Bicycle Priority Street is an essential component for creating an infrastructure aimed to the bicyclists.

1.1 Aim/purpose

The aim of this report is to investigate if an implementation of a Bicycle Priority Street in Sweden improves the traffic safety and contributes to reach the goal in Vision Zero. The potential and effect of different Bicycle Priority Street-designs regarding the infrastructure and the traffic safety compared to having mixed traffic is evaluated. In order to investigate this, the questions below are answered and recommendations given regarding:

- What is the aim of the Bicycle Priority Street?
- How should a Bicycle Priority Street be designed and what rules should be included?
- Where and when should it be implemented?

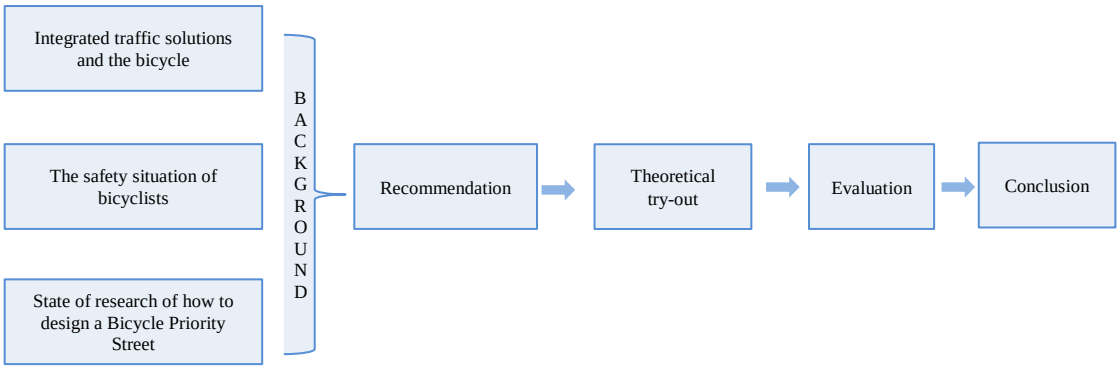
Other questions aimed to be answered during the process of the report are:

- What impact does the Bicycle Priority Street have on the character of the streets and infrastructure, the environment, the subjective safety/security and the availability?
- For which type of bicyclists is the Bicycle Priority Street suitable?

The report is intended to be read as inspiration and a handbook for consultancies, municipalities and people in this field and business who have common knowledge in traffic but perhaps not in traffic safety or in bicycles infrastructure.

1.2 Method

The work is divided into five different phases; **Background, Recommendations, Theoretical try-out, Evaluation** and **Conclusion**, as can be seen in the flow chart below.



In the background a literature study about **Integrated traffic solutions and the bicycles** is first conducted. Then the impact speed has on road accidents is researched. Also an analysis with the accident statistics database STRADA is conducted to evaluate the **Bicyclists traffic safety situation;** who get injured on local streets, why this happens and what streets are the most problematic. One area/neighborhood in Gothenburg is analyzed and the findings investigated in other, similar areas are used in order to evaluate if this is a pervasive phenomenon. Study visits to locations where Bicycle Priority Street or similar are operating and literature studies are used in **State of research of how to design a Bicycle Priority Street** of the roads. Literatures that lay as a basis for the literature study are *Design manual for bicycle traffic*,

Åtgärdskatalogen för säker trafik i tätort, GCM-handbok, The Handbook of road safety measures and *VGU* explained below:

Design manual for bicycle traffic by CROW (The Dutch national information and technology for infrastructure, traffic, transport and public space), 2007, is a manual that describes the steps required to create a bicycle friendly infrastructure.

Åtgärdskatalogen för säker trafik i tätort (The measure catalogue for safe traffic in urban areas) by SKL, (Swedish Association of Local Authorities and Regions), 2009, is a catalogue which compiles information about research on traffic safety measures effects and practical experience around design and maintenance.

GCM-handbok – Utformning, drift och underhåll med gång, cykel- och mopedtrafik i fokus. (Design and maintenance-handbook with focus on pedestrians, bicyclists and mopedists) by SKL, 2010, is another handbook describing solutions which highlights the position of the pedestrians and bicyclists.

The Handbook of Road Safety Measures by Elvik et al, 2009, is a meta-analysis that has gathered results from over 2000 evaluation studies and describes 128 measures in order to improve traffic safety.

VGU - Vägar och gators utformning (Road and streets design) by SKL and Trafikverket (The Swedish Road Administration), 2012, is a collection of requirements and recommendations about how streets and roads should be designed in Sweden.

The background concludes with **Recommendations** and discussions of different factors on the Bicycle Priority Street. Qualities, such as character of the streets and infrastructure, the environment, the subjective safety/security and the availability for different measures are used to weight the suggested designs against each other. The recommendations include the function of the Bicycle Priority Street, the required intensity, speed limit and rules, plan type, surface, parking, intersection, speed reducing facilities and signs. A SWOT (Strengh, Weakness, Opportunity, Threat) analysis and developed method tools from *Lugna gatan* by SKL (1998) and *Trafik för en Attraktiv Stad* by Boverket et al (2004) are used for the evaluation. A group of experts; professionals in the traffic planning field working as consultants, in municipalities and in the Swedish Transport Administration, are being used as an evaluation panel in the work of assemble the recommendations.

Theoretical try-outs of the recommended designs of a Bicycle Priority Street are conducted on three streets in Majorna, Gothenburg, Sweden. This is used to make an **Evaluation** of how the infrastructure and traffic safety are impacted. The evaluation of the urban space includes qualities on the character of the street, the modal split, the environment and subjective safety/security. The result is shown in a value rose.

The evaluation of the traffic safety impact is performed in two ways. The speed affects the probability of an accident to happen, and this change of probability is compiled for the try-out streets. Also verified effects are evaluated and found and together with traffic safety relationships, the traffic safety is evaluated.

The **Conclusion** sums up the findings and the impact that Bicycle Priority Street has on the infrastructure and the traffic safety. It also gives recommendations of where to implement a Bicycle Priority Street, how to implement it, what rules to implement and how to design it.

1.3 Delimitations

This report focuses on Bicycle Priority Street and not on bicycles, meaning that all road users on the street are in the analysis. Disabled people and pedestrians and other

road users using the sidewalk are not included. This report does not include a discussion weather Bicycle Priority Streets should be implemented on streets in Sweden, but an investigation and discussion about the potentials and effects on the traffic safety and the urban space if it is being implemented.

The work of traffic safety is commonly divided into three factors; the road, the vehicle and the behavior. Bicycle Priority Street influences the road and this is where focus is situated and attitudes towards Bicycle Priority Street before and after the implementation and how to inform the citizen is not focused upon. Other factors not investigated deeply are costs, mopeds, public transport as well impact on the traffic safety in the surroundings.

2 Integrated Traffic Solutions and the Bicycle

Bicycling is a sustainable transportation mode for several reasons such as no contribution to neither noise nor emissions, not demanding much space and it is efficient regarding energy demands (SKL, 2010). Furthermore it is an everyday workout and does not contribute to traffic jam. In Sweden ten percent of all passenger transportation is done with bicycles, and cities with high quality bicycle network and with a large amount of bicyclists are often considered attractive and living. An attractive environment includes sustainability and is a place where people want to be.

Bicycles are powered by muscles and their network should therefore be direct, not have any unmotivated stops and no big level differences (SKL, 2010). Hence, it is required to build a bicycle network adjusted for these needs and it is also essential to treat the bicycles as a separated traffic mode. In the work of increasing the share of bicyclists it is important to show that the bicycles are prioritized and thought of in the infrastructure. The accessibility for the bicyclists therefore needs to be improved but in such way that the goal of Vision Zero is aimed. To develop the traffic safety for bicyclists the operation and maintenance needs to be improved and more research of innovative solutions in traffic safety be conducted and implemented.

A challenge when planning infrastructure for bicyclists is that it is a heterogeneous group of road users with different presumptions. In Sweden, when calculating on the bicyclists speed, it is most common to use the speed 15-20 km/h (SKL, 2010). Trafikverket et al (2012b) recommends using the speed 16 km/h but also mentions that fast bicycles, like fitness bicyclists, can keep speeds like 40 km/h while children and elderly keeps lower speeds than 16 km/h. The variations in speed between bicyclists are the largest in slopes, both up and down.

The bicycle network is divided into the main and local network (SKL, 2010). The main network contains of longer distances and connects different neighborhoods and important target points. It should be separated from the motorized vehicles on either separated bicycle paths or lanes, but shorter stretches can be in mixed traffic. The local network is on shorter stretches and connects the main network. The main bicycle network is recommended be dimensioned for a bicycle speed of 30 km/h and the local network for 20 km/h (Trafikverket et al, 2012b). The priority in operation and maintenance and whether they are prioritized in intersections differ between the two. The local bicycle network can be located on local streets which are characterized with low traffic, less availability and a high amount of driveways and the allowance of parked cars depend on the regulations of the municipality (Boverket, 2012). A local street is a road where the traffic is aiming somewhere on street. The design on these streets should contribute to low speeds of the traffic.

In the thesis *Utvärdering av cykelfälts effekter på cyklisters säkerhet och cykelns konkurrenskraft mot bil* (Evaluation of the effects of bicycle lanes on bicyclists traffic safety and the ability of bicycles to compete with motorized traffic) by Nilsson (2003) both a literature study and a before- and after study are conducted to evaluate the traffic safety effect on bicycle lanes. According to the evaluation, the bicycle lanes improve the traffic safety for the bicyclists on longer main streets with a large bicycle flow. On streets with low traffic and no centerline, however, the traffic safety is then worsening compared to have the bicycles mixed with other traffic. When bicycle lanes are implemented on bigger roads, the speed does not change remarkable. But when implemented on smaller streets without centerlines the speed is on the other hand arisen, probably because the drivers of the motorized vehicles do not focus as much

on the bicycles. Also in intersections a mixed traffic is preferred in a traffic safety point of view (SKL, 2012). To have the bicycles in the same space as the motorized vehicles make them more visible than when making them cross the street on a separate bicycle path.

2.1 Shared Space

On stretches with mixed traffic the bicyclists drive on the permission of the motorized vehicles, and since it is considered a street for cars it makes the bicycles guests on the street. This lowers the attractiveness of the bicycles. To create a space where all road users are on the same permissions, the concept shared space has been implemented in several locations in Sweden. Shared space is a common space created for all road users; both protected and unprotected (Trafikverket, 2011). It is a vividly space contributing and inviting social integration and free movement even though traffic is present.

Shared space is considered to improve the traffic safety for several reasons; the subjective safety/security is low which contributes to more integration and more observant road users, the speed is reduced and traffic flow of motorized vehicles is lower while the flow of unprotected road users is larger (Trafikverket, 2011). One disadvantage with shared space is that the subjective safety/security is considered to not satisfy the demands of elderly, children and disabled peopled because of the required interaction between the road users.

Shared space can either be unregulated or regulated (Trafikverket, 2011). Unregulated shared space is on locations with only general traffic rules meaning that the vehicles, both motorized vehicles and bicycles, are using the right hand priority rule. The pedestrians can cross the road if it is considered safe and do not disturb the surrounded traffic. Regulated shared space has local traffic regulations where the vehicles give priority to the pedestrians.

Example of regulated shared space is urban play streets. Motorized vehicles are allowed when driving on the terms of the pedestrians, hence in the same speed and they must give way to the pedestrians (SKL, 2010). The street has to show by its design that the pedestrians are the dominated traffic mode and should use the whole street (SKL, 2009). Therefore, no differentiation between street and pavement should exist.

An urban play street increases the attraction of the pedestrians, the flow is therefore bigger than before which contributes to lower speed of the motorized vehicles (SKL, 2009). The space does also make its users confused about how to act on the street and what rules are valid, which increases the attention of the users. The traffic safety is improved with 25 percent, including all type of injuries, not only severe and fatal (Elvik et al, 2009). The speed limit is walking speed, often mentioned as seven km/h, but the mean speed of the motorized vehicles is often 15 km/h (SKL, 2009).

One good example of an unregulated shared space often mentioned is the square Skvallertorget in Norrköping, Sweden. It was reconstructed in year 2000, it was earlier an intersection and today it is a square with the speed limit of 30 km/h and created as a shared space where an interaction between all road users is required (Tyréns, 2007).

The document *Trafiksäkerheten vid shared space* (Traffic safety at shared space) by Tyréns (2007) is a behavior study of the square. When Skvallertorget was an

intersection five to six accidents happened per year, one of them severe. After the reconstruction, during the years 2003 to 2007, only three accidents occurred and none of them severe. During three days the behavior and the interaction between the road users was studied at this location and afterwards this evaluation was conducted.

The speed limit at the square is set as recommended 30 km/h, but it is built in order to have a speed level of 15-20 km/h. This speed is essential to ensure a good communication and interaction between the different road users. This can be concluded when evaluating the share of motorists in different speed levels that gives way to the bicyclists, see Figure 1 below. The mean speed is 16-20 km/h, and during night time it raises up to 26 km/h.

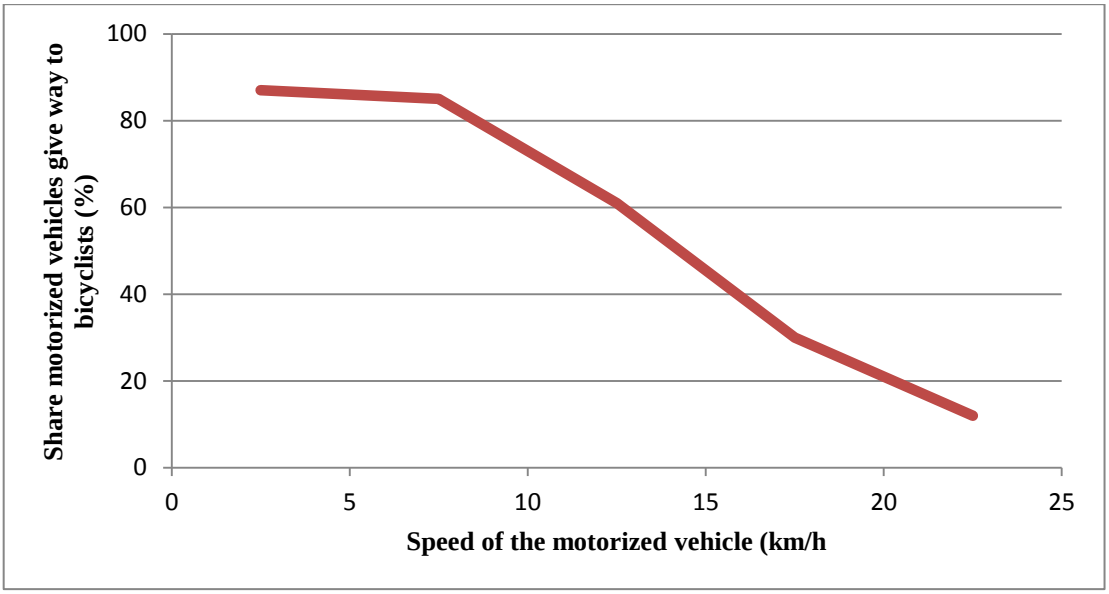


Figure 1 Share of motorists that give way to bicyclists depending on the speed (Tyréns, 2007).

The speed of the motorized vehicles is remarkably different between the ones who continue driving as before and the ones that stop or give way for the bicyclists, see Figure 2 below. At the higher speeds level of the motorized vehicle, 20-30 km/h, it can be seen that the motorized vehicle continue as before when interacting with bicycles. With lower speeds the motorized vehicles give priority when interacting with bicyclists.

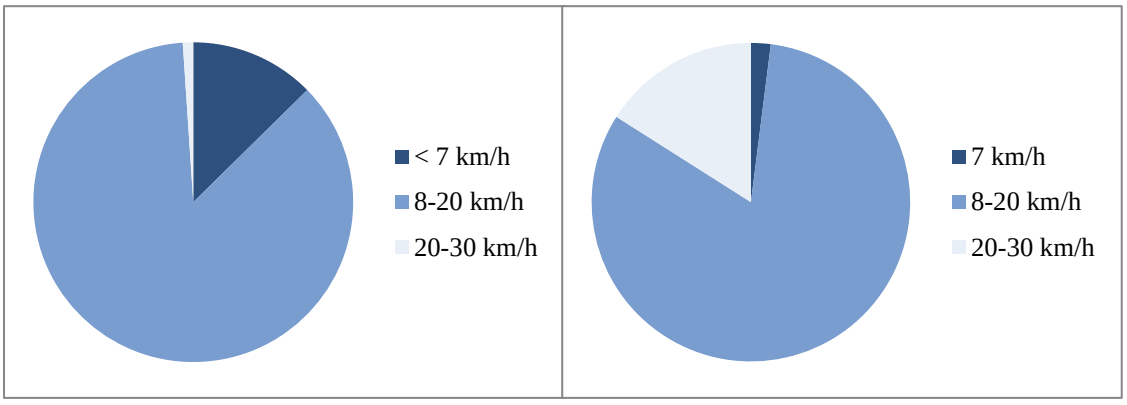


Figure 2 Speed when motorist stop and give priority when interacting with bicyclists, to the left. Speed when motorist continue as before when interacting with bicyclist, to the right (Tyréns, 2007).

The connection between the number of bicyclists and if the motorized vehicle stop and give priority is not clear in the evaluation. The speed and when the motorized

vehicles stop and give priority is however clear as can be seen in Figure 2 above. A low speed is essential in order to have the road users to interact.

During the behavior study 15 percent of the bicyclists stopped bicycling and started to walk instead when entering the square, compared to three percent that do this when crossing a road at a bicycle crossing. The proportion increases with a raising age. This shows that vulnerable road users are not comfortable in this situation. Skvallertorget has a large number of pedestrians but the number of bicycles is not noted. The number of motorized vehicles was reduced from approximately 20 000 to 14 000 vehicles per day when reconstructing it. A large proportion of the motorized vehicles stops and adjusts the speed in spite of the unprotected road uses, which can be seen as an indicator that the interaction is good.

2.2 Bicycle Priority Street

Bicycle Priority Street is a regulated shared space solution but on the bicyclists conditions. It is implemented in several countries. The definition differs and known countries that use streets where bicycles are prioritized and motorized vehicles are permitted are Germany, the Netherlands, Belgium and Austria. In German the Bicycle Priority Street is called Fahrradstrasse, in French Rue Cyclable and in Dutch it is called Fietsstraat, which all directly translated means bicycle street. Also in Aarhus in Denmark, a try-out of has been discussed (Vejdirektoratet, 2012).

In Germany the concept Bicycle Priority Street has been used since the beginning of the 1980s and was included in the national traffic regulations in 1997[1]. In both Belgium and Austria the concept is relatively new, Austria had it included in the traffic regulation in March 2013 and Belgium in the beginning of 2012 (Bundeskanzleramt, 2013 & ELTIS, 2012). In the Netherlands, on the other hand, it is today not included in the traffic regulation but the concept has been used since the beginning of the 1990s when the first was implemented in Goes, in the Netherlands[2].

As mentioned, the concept of Bicycle Priority Street has been a common solution in the infrastructure for a long period in both the Netherlands and Germany and both are considered nations with a high share of bicyclists. Therefore their designs and concept have been used, developed and evaluated for a longer time. Therefore this report mostly brings up measures and findings from these countries.

In Sweden the concept of Bicycle Priority Street is not included in the traffic regulations but the concept does exist in Linköping since 2007 when the municipality implemented it on two streets and therefore examples from Linköping are demonstrated (Västerås Stad, 2009).

In year 2012 the so called *Cykelutredningen* (The bicycle investigation) by SOU (Swedish Government Official Reports) was published (SOU, 2012). The *Cykelutredningen* is an investigation where the rules and conditions that affect the bicyclists in Sweden are investigated. One of the recommendations in *Cykelutredningen* is that Bicycle Priority Street should be implemented in the Swedish traffic regulations.

[1] Hamburger, W (Dipl. Ing. In the Municipality of Bremen) (2013-01-30) *Fahrrastrasse in Bremen.* Personal mail contact with S. Johansson (sofiejo@student.chalmers.se).

[2] Herbert Tiemens (Traffic Expert at the Region of Utrecht) interviewed by the authors March 14 2013.

2.2.1 Functions

In Table 1 below the Bicycle Priority Street is further explained by highlighting the *definition*, the *motive* of implementation, the wanted *locations* and the *demands* of the Bicycle Priority Street in different countries, whether this information has been found.

Table 1 The definition, motive, location and demand of the Bicycle Priority Street in different countries.

Germany		*A street for bicycles where other traffic modes are permitted (StVO, Anlage 2, ifd.Nr 23)*
	Motive	• Fill out a missing link in the bicycle traffic network (Schenk, 2013) • Have a motivational effect for more bicyclists, since it gives the bicyclist the feeling of being accepted as an important traffic participant (Schenk, 2013) • Cost-effective bicycle infrastructure (Schenk, 2013) • Aggregate bicycle traffic in a residential area into one street (Schenk, 2013) • Work as safe routes to schools[3] • Encourage an interaction between the different road users[3]
	Location & demands	• Streets with the speed regulation 30 km/h to ensure the safety (StVO, Anlage 2, ifd.Nr23). • Streets where the bicycle is, or is expected to be, the dominating traffic mode (Schenk, 2013) • Residential areas with a maximum of 30 percent drive-through motorized traffic[3]. Much drive-through traffic contributes to a lower patients for the motorized vehicles of staying behind the bicyclists compared to motorized vehicles having their goal on the Bicycle Priority Street. • The bicyclists are allowed to bicycle side by side on the Bicycle Priority Street but not hinder the motorized traffic to overtake them, and on the other hand the motorized vehicles are not allowed to force the bicyclists to the side to give them space (StVO, Anlage 2, ifd.Nr23). • Public transport and foreign traffic are considered to not fit on a Bicycle Priority Street. The foreign traffic might have troubles with understanding the rules and the public transport would be degraded if it had to prioritize the bicyclist (Schenk, 2013).

[3] Stephan Böhme (Traffic Engineer at the Municipality of Münster) interviewed by the authors March 13 2013.

The Netherlands	*A road in a residential area that forms a main bicycle route (CROW, 2007). Motorized vehicles occur to a limited extent and as subordinate traffic; the Bicycle Priority Street is mostly aimed for commuting bicyclists[4].*	
	Motive	• Fill up missing links in the bicycle network[4] • Use as a traffic calming measure[4] • Decrease the number of motorized vehicles on the street[4] • A dense bicycle infrastructure solution (CROW, 2007) • Cost-effective bicycle infrastructure (CROW, 2007) • Improve the accessibility for motorized vehicles compared to the alternative of having a bicycle path on the same spot (CROW, 2007) • Improve the subjective safety/security compared to have separate bicycle path in a recreational area (CROW, 2007)
	Location & demands	• Residential areas[4] • Streets with a majority of local motorized vehicles since these motorist feel a greater responsibility than motorized drive-through traffic[4] • Streets with as low amount of drive-through motorized traffic as possible[4] • Dead-end-streets for motorists and drive-through-streets for bicyclists[4] • The design and layout should easily show the function of the Bicycle Priority Street (CROW, 2007)
Belgium	*A street created for bicyclists but where motorized vehicles are allowed (Belgisch Staatsblad, 2012)*	
	Motive	• Make a street more attractive for bicyclists (ELTIS, 2012) • Improve the traffic safety on the street (ELTIS, 2012)
	Location & demands	• Streets where the speed never exceeds 30 km/h (Belgisch Staatsblad. 2012) • Motorized vehicles are not allowed to overtake bicycles (Belgisch Staatsblad, 2012)
Austria	*A street where vehicles are forbidden except for bicyclists, suvielliance vehicles and motorized vehicles heading the street (Bundeskanzleramt, 2013)*	
	Motive	• Improve the traffic safety (Bundeskanzleramt, 2013) • Improve the availability for the bicyclists (Bundeskanzleramt, 2013) • Increase the number of bicyclists (Bundeskanzleramt, 2013)
	Location & Demands	• Streets with the speed limit 30 km/h (Bundeskanzleramt, 2013) • Streets where bicyclist are not hindered by obstacles (Bundeskanzleramt, 2013)

[4] Herbert Tiemens (Traffic Expert at the Region of Utrecht) interviewed by the authors March 14 2013.

Linköping, Sweden	*A street where bicyclists and motorized vehicles share the same space and the bicyclists are prioritized (Vägverket, 2007)*	
	Motive	• Increase the amount of bicyclists (Vägverket, 2007) • Create safer and more accessible bicycle networks for children, families and elderly (Vägverket, 2007) • Canalize the bicycle traffic into the street (Vägverket, 2007) • Improve the interaction between bicyclists and motorists compared to an ordinary mixed traffic street (Vägverket, 2007) • Make the motorists show more respect to bicyclists (Vägverket, 2007) • Create a more attractive city for the unprotected road users by decreasing the barrier-effect (Vägverket, 2007) • Less noise and better quality of air because of less motorized traffic (Vägverket, 2007) • Cost-effective bicycle infrastructure (Vägverket, 2007)
	Location & Demands	• Streets where the bicyclists already are the dominating road users[5] • Streets close to the city center[5] • A recommended speed limit of 20 km/h[5]
Cykelutredningen (SOU, 2012)	*A street where the motorized vehicles adapt their speed to the bicycle traffic*	
	Motive	• Increase the bicyclists availability • Show the bicyclists that they are a prioritized in the traffic environment
	Location & Demands	• Streets where parking for motorized vehicles can be arranged on special parking lots • Streets where it can be arranged for the Bicycle Priority Street to have priority in intersections

The definitions of a Bicycle Priority Street in the different countries differ, but the content is the same; it is a bicycle street where the motorized vehicles are allowed on the permissions of the bicycles. The motives and requirements differ, and also the scope of available information. Often there are no motivations of the requirements, for instance it is mentioned that the traffic safety is improved but not in which way.

2.2.2 Intensities

When implementing a Bicycle Priority Street, the idea is to attract all bicyclists in the area so that the majority uses the Bicycle Priority Street instead of the parallel roads. Also, an infrastructure that demonstrates that the aim is to please the bicyclists might as well attract new bicyclists, earlier using other traffic modes.

The condition that the bicycle traffic has to dominate the Bicycle Priority Street is important since this itself shows the bicyclists priority and has a traffic calming effect (CROW, 2007). In the Netherlands a Bicycle Priority Street is mostly implemented on main bicycle routes and therefore a superior number of bicycles should be self-evident. When the Bicycle Priority Street was implemented in Linköping, Sweden, the

[5] Hahn, P-E (2013-02-26) *Cykelfartsgator* [Bicycle speed streets. In Swedish]. Personal mail contact with S. Johansson (sofiejo@student.chalmers.se).

domination of bicycles already existed on the streets and this domination is considered to keep up the function of the street[6]. To have more bicycles than motorized vehicles is more important the longer the street is[7]. This is to ensure that the motorists use the Bicycle Priority Street on the bicyclists' conditions and in addition a larger flow of bicyclists leads to a reduced speed of the motorized vehicles.

To ensure the bicycles domination of the motorized vehicles different shares of the transportation modes are desirable in different countries:

- The Netherlands: bicycle intensity = 2 x motorized vehicles intensity (CROW, 2007)
- Germany and Sweden: bicycle intensity > motorized vehicle intensity (Schenk, 2013 & Hahn, 2013)

The domination of the bicyclists does not have to be the case when implementing the Bicycle Priority Street but then the road authorities are recommended to try to reduce the intensity of motorized vehicles (CROW, 2007 & Schenk, 2013).

Besides the comparable shares of the different modes of transport some other intensities are recommended on a street that is declared as a Bicycle Priority Street to ensure the bicyclists domination. The ones found can be seen below (CROW, 2007):

- 1000 bicyclist/day - minimum the Netherlands
- 2000 PCU/day – maximum in the Netherlands
- 3000 PCU/day – maximum in Germany
- <500 PCU/day – no modification needs to be made to the street in the Netherlands

To make the Bicycle Priority Street streets dead-end-streets for motorized vehicles or implement it on dead-end-streets is a good way to ensure as low amounts of motorized vehicles as possible[7]. This ensures that it is mostly local road users, which are considered to drive more carefully than drive-through traffic, on the street because the road user can only reach targets located on the street.

A study made by Ekman 1996 shows that the number of severe conflicts per bicycles decreases abruptly when there are more than 50 bicyclists per hour (Ekman, 1996). A severe conflict is a conflict that marginally could be an accident, not only severe or fatal accident. The flow of the bicyclists is more important than the design, motorized vehicle flow and type of street. How this would change during winter season as well as how it effects the surrounding streets needs however to be investigated further.

2.2.3 Traffic Regulations

In Germany, Austria and Belgium the Bicycle Priority Street is included in the traffic regulation (StVO, Anlage 2, ifd.Nr 23, StVO 1960:§67, Belgisch Staatsblad, 2012). The traffic regulations include the speed limit, the sign, if motorists are allowed to overtake bicyclists and if bicyclists are allowed to bicycle side by side. In the Belgian and the Austrian traffic regulations it is also included what the conditions on the street should be when implementing a Bicycle Priority Street.

In Sweden Bicycle Priority Street is not included in the traffic regulations, hence there are no national regulations of how they should be designed, what rules the road users follow and which traffic signs to use. Bicycling side by side is not changed at the Bicycle Priority Street, bicyclists shall on all streets, according the Swedish traffic

[6] Hahn, P-E (2013-02-26) *Cykelfartsgator* [Bicycle speed streets. In Swedish]. Personal mail contact with S. Johansson (sofiejo@student.chalmers.se).
[7] Herbert Tiemens (Traffic Expert at the Region of Utrecht) interviewed by the authors March 14 2013.

regulations, drive after each other, but when no danger or disturbance it is allowed to drive side by side (Chapter 6, 1§ SFS 1998:1276). However, according to §33 and §38, to be permitted to overtake then the overtaking vehicle shall be able to leave a comfortable distance, and the vehicle that is being overtaken shall keep right as much as possible in order to facilitate.

In the Netherlands there are also no traffic regulations about how a Bicycle Priority Street is to be constructed, which has led to several types of designs[8]. CROW, the Dutch technology platform for transport, infrastructure and public space, has made a design manual for bicycle traffic in the Netherlands. There are recommendations on where to implement and how to design a Bicycle Priority Street. If there is a trial about an accident this manual is where the judge makes its judge upon[8].

2.2.4 Evaluations

A small number of evaluations have been found on different effects of the Bicycle Priority Street today, the results can be seen in Table 2 below.

Table 2 Evaluation of the Bicycle Priority Street.

People´s opinion	A not yet published questionnaire study of the road users attitude and behavior on a Bicycle Priority Street in Linköping has been conducted by Forsberg (2008). The result shows that the bicyclists are the road users most satisfied with the Bicycle Priority Street but they do not have the impression that the implementation has increased their safety and security. The bicyclists find that their availability is increased significantly while the motorists have the impression that the bicyclists have more space and bicycle more side by side than before the implementation. The road users are positive to the reduced speed on the street, from 50 km/h to 20 km/h, but it is considered that the road users do not obey the speed regulations.
Attraction of bicycles	In Belgium the total amount of bicyclists using the Bicycle Priority Street on Visserij, their first Bicycle Priority Street, raised from 1706 to 2568, with 44 percent, the first 15 months after implementing it (ELTIS, 2012).
	In the not yet published questionnaire study conducted by Forsberg (2008) it can be seen a small raise of bicyclists after the implementation of a Bicycle Priority Street on the evaluated street. The study shows insignificantly decline in the amount of motorized vehicles before and after the implementation.
Traffic safety and speed	In Belgium the number of motorized vehicles exceeding the speed limits decreased with 80 percent (ELTIS, 2012)
	One evaluation has been made of the Bicycle Priority Street in Linköping by VTI, which was presented at Transportforum 2009, but never was published (Lindberg, 2009). This evaluation showed that since the implementation of the speed limit 20 km/h the motorized vehicles' speed had decreased to 25 km/h which is around five to ten percent. The amount of motorized vehicles on the street had also decreased, also with five to ten percent. From the decrease in speed and amount of vehicles it was evaluated that risk of severe injury decreased with 10-20 percent and fatal by 20-25 percent. The study also showed that 10-20 percent more motorized vehicles gave priority to the bicycles after the implementation.
	Even if Bicycle Priority Street is common in Germany and the Netherlands no evaluations of traffic safety have been found from these countries.

[8] Herbert Tiemens (Traffic Expert at the Region of Utrecht) interviewed by the authors March 14 2013.

Urban play streets and shared space are, except for the tryout in Linköping, the most similar situations to Bicycle Priority Street in Sweden. Shared space can, as earlier mentioned, either be regulated or unregulated. When unregulated, all road users use the same space on the same conditions. On a Bicycle Priority Street the motorized vehicles use the street on the conditions of the bicycles, making the situation differ. The behavior of the road users and how and when they interact can however be assumed to be similar. Hence, many lessons can be taught and conclusions taken.

3 The Safety Situation of Bicyclists

This chapter describes the traffic safety situation for the bicycles. In order to investigate how to create a safe infrastructure for the bicycles, the reasons for accidents are investigated. These can be used in order to improve the traffic safety. In this report, both bicycle accidents in Sweden, national, and statistics from local streets in a randomly chosen neighborhood are evaluated. The neighborhood used for the investigation is Majorna in Gothenburg, and the accidents there reported to STRADA have been studied. This neighborhood is later used when conducting theoretical implementations. To have an indication if this pattern compiled in Majorna is specific for Majorna or generally for an urban district in Sweden, the accidents in another, also randomly chosen, district have been studied in order to use as a comparison and evaluate if this is a pervasive phenomenon.

Evaluation of the traffic safety is mostly conducted in two ways, either to make before and after studies or to compare a measure with similar locations without the implemented measures (SKL, 2009). Making before and after studies is the most common way and demands data from long time periods. The so called effect of regression and migration needs to be taken into account, which is important to know to assure that the result is not overvalued. Regression is a statistical phenomenon due to an incorrect sample (for instance the spot was chosen due to an abnormality thought to be randomly, but if the abnormality just was a coincidence the reduced accident rate was not dependent on the implemented measure), while migration means that the problem is not solved; only moved to another location. As earlier mentioned, Bicycle Priority Street is today being used in the Netherlands, Germany, Austria and Belgium. To evaluate how the traffic safety has changed in these locations after the implementation would be the most truthful way to obtain the impact the Bicycle Priority Street has on the traffic safety. Unfortunately, in neither of the countries the accident statistics and other data have been found in order to evaluate how the traffic safety changed after implementing a Bicycle Priority Street.

A higher technology and new innovations reduce the severity of injuries of drivers and passengers in car accidents; one example of this is air bags. However, this protection is often compensated with a higher speed; the safer a road user feels the more risk he or she takes which means that a high subjective safety/security sometimes contributes to a reduced actual safety (SKL, 2009). Hence, the airbag and therefore the increased subjective safety/security does not shield the unprotected road users such as pedestrians and bicyclists. For them the speed limit is also the limit between life and death. Speed has a strong relationship with accidents, both regarding probability and consequence.

3.1 Speed and Traffic Safety

Half of the fatal accidents in urban areas occur when all traffic rules have been followed, which indicates that the design of the road does not correspond to the function of the road and the speed limits, and vice versa (SKL et al, 2008). In order to conduct speed limits that better correspond to the design, the steps of the speed limits were in 2008 extended to steps of 10 km/h, from 30 to 120. The municipalities can now change the speed limit in an urban area, or in a part of an urban area, from 50 km/h to not only 30 km/h but also 40 km/h. This also contributes to a better compliance of the speed limits, a decreased environmental effect and better traffic

safety. When this new system was introduced, it was pointed out that the system still needs to be homogenous and not cluttered.

In the report *Slutrapport utvärdering nya hastighetsgränser* (Final report evaluation of new speed limits) where Trafikverket (2012c) evaluates the new speed limits 40, 60 and 80 km/h, there is a suggestion for making 40 km/h the normal/base speed in urban areas instead of 50 km/h which is used today. This is due to that 30 or 40 km/h are the most common speed limit when using guidelines from Trafikverket. The reason for choosing 40 instead of 30 km/h is because the traffic work otherwise gets bigger and the acceptability from road users and authorities would be greater. This speed limit would, as today, be able to adjust both up and down in the cases that the traffic safety, accessibility and environment allow or demand it. During the try-out year of implementing a Bicycle Priority Street in Linköping the speed limit was 20 km/h. When the municipality of Linköping decided to extend the try-out for some more years, this speed limit was not allowed since it does not exist in the Swedish traffic regulation. Instead, the speed limit had to be set as a recommended speed limit of 20 km/h.

When decreasing the speed limit from 50 km/h to 40 the average speed is reduced with three km/h, and the average travel time increases with two to five percent (SKL et al, 2008). This speed limit does not only make the flow smoother but reduces the accidents by 25 to 30 percent. The number of severe and fatal accidents is reduced by eight percent. According to SKL et al (2008) the speed limit where bicycles and pedestrians cross the street should be 30 km/h to assure a safe crossing. It should also be 30 km/h where cars and unprotected road users meet.

The speed of the vehicles both influences the probability and severity of an accident (SKL et al, 2008). A higher speed leads to, logically, driving a longer distance during the reaction time and therefore the probability of an accident is increased. The reaction time of the drivers is usually around one second, making the reaction distance the stretch you drive during that second. This means that a vehicle driving in 30 km/h has a reaction distance of 8,3 meters. In 50 km/h this would be 13,9 meters instead. The stop distance is the stretch from when the driver starts to break to when the vehicle stands still, which also depends on the speed and the conditions of the tires and road. As can be seen in Figure 3 below, a vehicle driving in 30 km/h has the total stopping distance of 14 meters, which is practically the same as the reaction time for the vehicle at 50 km/h. This means that that driver would not even have started to break to avoid a collision that the driver in 30 km/h would have avoided.

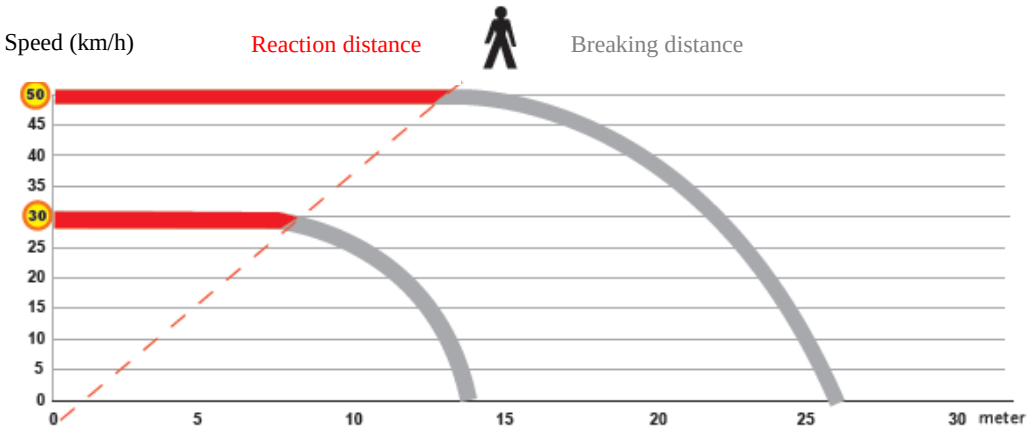


Figure 3 Stop distance = Reaction distance + breaking distance (Göteborgs Stad 2009)

To evaluate how the accident rate changes after modifying the speed, the so called power model can be used (Elvik et al, 2004). This equation can, by using different exponents, calculate the accident rate of both severe and fatal accident when the relative mean speeds are known.

$$\frac{Accidents_{after}}{Accidents_{before}} = (\frac{Speed_{after}}{Speed_{before}})^{x}$$

$x = 2{,}4\ (95\%\ confidence\ interval; 1{,}1 - 3{,}7)$ for severe and fatal accidents (Elvik, 2009)

A higher speed produces more kinetic energy which increases the severity of the accident (Göteborgs Stad, 2009). When getting hit in 50 km/h four out of five unprotected road users get fatal injuries as can be seen in Table 3 below (SKL et al, 2008).

Table 3 Consequences when unprotected road users get in an accident with a motorized vehicle (SKL et al, 2008).

Speed level	Probability of getting killed for unprotected road users in an accident with a motorized vehicle
20 km/h	Almost everybody survives
30 km/h	1/10 perish
40 km/h	3/10 perish
50 km/h	8/10 perish
70 km/h	Most probably leads to death

Generally 60 percent of the drivers exceed the speed limits (SKL et al, 2008). 20 percent drive more than 20km/h faster than allowed. The roads with 30 km/h are the ones that are exceeded the most (Trafikverket, 2012b). The exceeding of speed limits does not only contribute to a more unsmooth flow and a higher rate of accidents, but is the biggest contribution of feeling unsecure in residential neighborhoods (SKL et al, 2008).

The three most important measures to make less drivers exceed the speed limits are to (SKL et al, 2008):

- Ensure the speed limits correspond to the functions of the road
- Strive to make the design of the road contribute to a speed level that corresponds to the speed limit
- Have speed surveillance that is both efficient and strategically located where the problems are situated

It is also important to have homogenous speed limits to make the system in the city easy and lucid (SKL et al, 2008). In residential neighborhoods it is usually desired to have a freedom of being able to have your children running around on the nearby local streets without having to worry. If this is to be reality, the road demands a design where all the road users not are able to relax totally and where the traffic rules for pedestrians and bicyclists are followed.

SKL (2010) mentions recommendations on separation between motorized vehicles and bicycles for different speeds on the motorized vehicles. To be noted is that in combined traffic with bicycles and motorized vehicles the highest speed limit should be 30 km/h to ensure a bicycle network with good standard. When the speed limit is 40-50 km/h bicycle lanes is recommended to be acceptable at low intensities of motorized vehicles. Bicycle lanes are suitable where accessibility amongst grown-ups is prioritized. This is due to that bicycle lanes allow a higher speed than the bicycle

paths, which the more homogenous group grown-ups appreciate, hence they are not disturbed and interrupted by pedestrians since most bicycles paths in Sweden are combined with pedestrian paths.

3.2 Reasons for Accidents

The risk of being killed in traffic is five times higher when bicycling compared to going in a motorized vehicle (Johansson et al, 2012). Since the bicyclists are the vulnerable road users on a Bicycle Priority Street the street has to be designed after their safety needs. Hence, the focus of the following accident research is on accidents involving bicyclists and not the persons in the motorized vehicles and the following two chapters highlight reasons for accidents involving bicyclists.

3.2.1 National

The report *Tema cykel – skadade cyklister. Analys baserad på sjukvårdsregistrerade skadade i STRADA* (Theme bicycle – injured bicyclists. An analysis based on hospital reported injuries in STRADA) is a survey made by Niska et al (2009) for VTI, The Swedish National Road and Transport Research Institute and is a study of bicycle accidents in STRADA. The situation of accidents and injuries involving bicyclists from the years 2003 to 2006 is investigated, looking only at the injuries reported by the hospitals. The survey includes all injuries on bicyclists, reported in the time limit, but the following chapter focuses on the severe injuries since this is what the Vision Zero is about.

The survey shows that the most common accident type amongst bicyclists is the single accident and the second most common is collisions between bicycles and motorized vehicles. Single accidents are the reason for 71 percent of the severe injuries of the bicycle accidents. It can also be seen that the accidents between bicycles have quite a big share of the severe injuries, around seven percent. See Table 4.

Table 4 Percentage of severed injured on type of accident (Niska et al, 2009)

Type of accident	Percentage of the total amount of severe injured (ISS>=9)
Single accident (bicyclist)	70,6
Bicycle/pedestrian	1,4
Bicycle/bicycle	6,9
Bicycle/moped	1,2
Bicycle/motorized vehicle	19
Other	0,9
Total	100

The total amount of accidents bicycle/motorized vehicles has a larger proportion of severe accidents than the single accidents, meaning that the consequences of the collisions between bicycles and motorized vehicles are more severe than for single accidents. But since the single accidents occur more often, the total amount of severe accidents are generated from single accidents.

By the injured bicyclists from accidents with collision with motorized vehicles 31 percent happen on the road and 55 percent in crossings. So most of the accident type bicycle/motorized vehicle, with injured bicyclists, happen in crossings. Of the total accidents, most bicyclists, 40 percent, are injured in accidents on roads, 35 percent on bicycle paths, 17 percent happen in crossings and the rest on other, meaning that the reason is unknown.

Of the single accidents with injuries 23 percent have happened because of worsened road surface such as ice, snow, water and gravel. By these occurring because of bad surface, more happen on the bicycle path than in crossings and on the road. Other factors that are lightened in the survey as reasons for the single accidents with injured bicyclist are uneven surface, brick edges, fixed and unfixed hinders. Single accidents with injured bicyclist are more common on road (43 percent) than on bicycle path (37 percent).

In Table 5 it can be seen that most accidents with injured bicyclist in built up areas happen on streets with the velocity 50 km/h. It is in the study shown that it is more likely to get more severe injury the higher the speed is on the street. This compiles with the research in the Chapter 3.1.

Table 5 Share of injury at type of street in built up areas (Niska et al, 2009)

Speed	Severity of injury		
	ISS>=9 (Severe)	ISS<9 (Minor)	Total share of injured
30 km/h	8,2	10	11
50 km/h	81,1	82	84
70 km/h	6,9	3	3
Unknown	3,8	5	5
Total	100 %	100 %	100 %

3.2.2 Local

The urban district Majorna in Gothenburg consists of the four neighborhoods Stigberget, Kungsladugård, Sanna and Majorna, see Figure 4 below, and has both residential areas and local centrums with restaurants and shops and has a hilly topography with many slopes.

As a complement to the factors and subjects that are recommended to fill in in STRADA by the police and hospitals there is a possibility to describe the scenario of the accident. In this evaluation, the description of the accident scenarios have been used to fill in the missing information, and sometimes this has been used to make assumptions about the accident. The information about accidents is therefore varying. Some accident scenarios are detailed described while some are only mentioned as a tumbling accident.

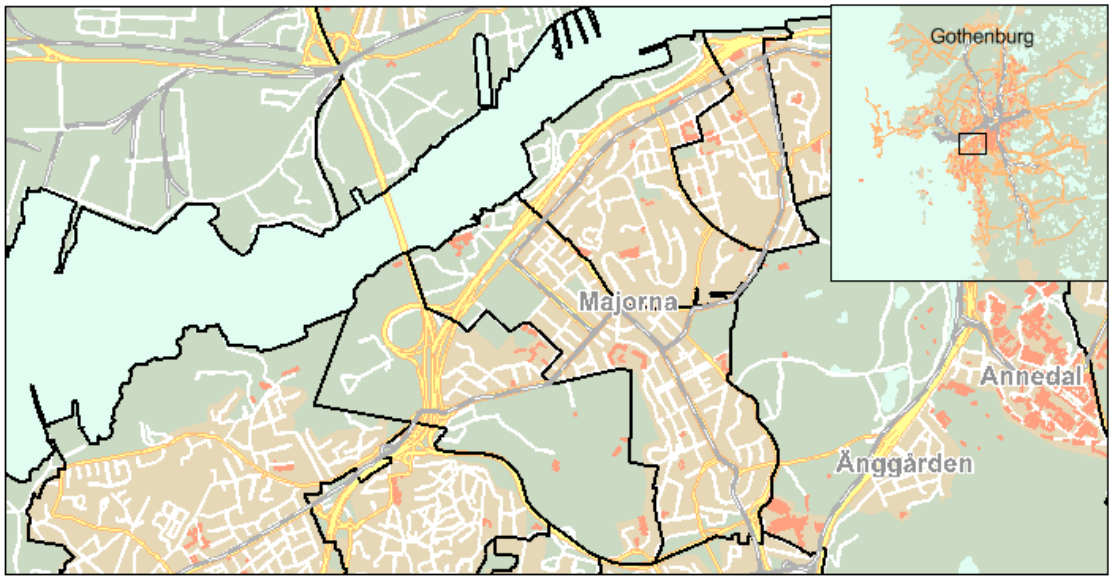


Figure 4 The area Majorna in Gothenburg. Map from Göteborg Stad (n.d a).

The evaluated accidents are accidents involving bicycles, and all are either severe or fatal, since those are the ones strived to extinguish according to Vision Zero. During the years 2000 to 2012, 41 severe and fatal accidents where bicyclists were involved Majorna according to the reports to STRADA from both hospitals and police during these years. The number of accidents are not few (41 lives have been impacted), but in the cause to use as statistical material they are rather few. Therefore this data should be used as an overview of the dangerous situations and phenomenon in the area. Table 6 and Table 7 below show a summary of all of the accident.

Table 6. Accidents involving bicyclists in Majorna (from STRADA)

Type of accident	Location	Number of accidents		Comment
Not relevant		6		Because of diseases, on school yards, 3 stuck in tram tracks
Car door	Street	5		Some assumptions have been made about location
Bicycle/ motorized vehicle	Street	7	9	
	Intersection	1		
	Pedestrian and bicycle path	1		
Bicycle/ bicycle	Pedestrian and bicycle path	3	3	
Bicycle/ moped		1	1	Not much information available
Single accident	Street	5	17	4 because of tumbling, 1 slipperiness
	Roundabout	1		Tumbling
	Intersection	3		1 tumbling, 1 driving into obstacles, 1 technical issues on bicycle
	Pedestrian and bicycle path	8		4 tumbling, 2 slipperiness, 1 bad pavement, 1 obstacles
Summery		**41**		
Number of relevant accidents		**35**		

Table 7. Number of accidents involving bicyclists in Majorna, sorted by location (from STRADA)

Location	Number of accidents	Percentage of all accidents
Roundabout	1	3%
Street	11	31%
Intersection	10	29%
Pedestrian and bicycle path	12	34%
Unknown	1	3%

As can be seen in Table 6 above, the most common type of accident with bicycles is single accidents, almost twice as many as the second most common; accidents with motorized vehicles. The single accidents happen mostly on the bicycle paths. Also of the locations of the total accidents, the bicycle paths are the ones where most of the accidents occur, while, logically, all the accidents with motorized vehicles are on streets. There is however one exception with an accident involving a motorized vehicle on a bicycle street, which happened when a caretaker was driving in the park Slottsskogen.

The reason for a single accident is commonly mentioned as tumbling, which does not describe the process. The accidents when bicycles drive into another bicycle have only been three. On the other hand, this accident includes two bicycles, making six bicycles being involved. Only three persons were injured severely. Only one accident

involves a moped, making the probability low. However, the proportion of mopeds in Majorna is unknown and mopeds are not focused upon in this report. Accidents when the motorized vehicles open the doors so that bicycles drive into them are many.

To make a conclusion of where the probability of an accident is highest, the proportion of bicyclists of the different roads is needed. In this evaluation and on this specific neighborhood, this number is not known. Therefore, the data from the accidents is to be used as an overview of where in Majorna most accidents occur.

To evaluate if the accidents above are specific for Majorna or commonly happening in similar sized area the accidents are compared with the accidents in Borås and Mölndal. Those areas are chosen randomly, the only demands were to use neighborhoods with residential areas and with a similar size as Majorna. Also, the statistics for the national mentioned in Chapter 3.2.1 are being used in the final comparison.

In Borås, the total numbers of accidents with bicycles has been studied in the areas Byttorp/Tullen, Tandared and Hulta. The total number of accidents is much lower, only six accidents have been registered. But to be noticed is that the hospital in Borås has only been connected to STRADA since May 2006, meaning that the reports from 2000-2006 are only from the police (Transportstyrelsen, 2011). However, the most relevant reason is probably due to fewer bicyclists and a different infrastructure. In Mölndal, the number of accidents is 16, and the Mölndal hospital has been connected to STRADA since October in 2000. The neighborhoods evaluated are Bifrost, Solängen, Åby and Mölndal Västra. Since the number of accidents is small in both Borås and Mölndal, these have been investigated as one study group.

In Appendix I a map with the areas are to be found together with a more detailed description of the accidents in the neighborhoods.

As can be seen in Figure 5 on next page, the single accidents in Majorna are, as in Borås and Mölndal, almost half the amount of the single accidents happening in Sweden according to Niska et al (2009). The percent of accidents with motorized vehicles is the same in Majorna as in the study from made by Niska et al (2009). In Borås and Mölndal there are even more accidents with motorized vehicles than single accidents. In all three studies the accident types bicycle/bicycle, bicycle/moped and bicycle/pedestrians are all below ten percent.

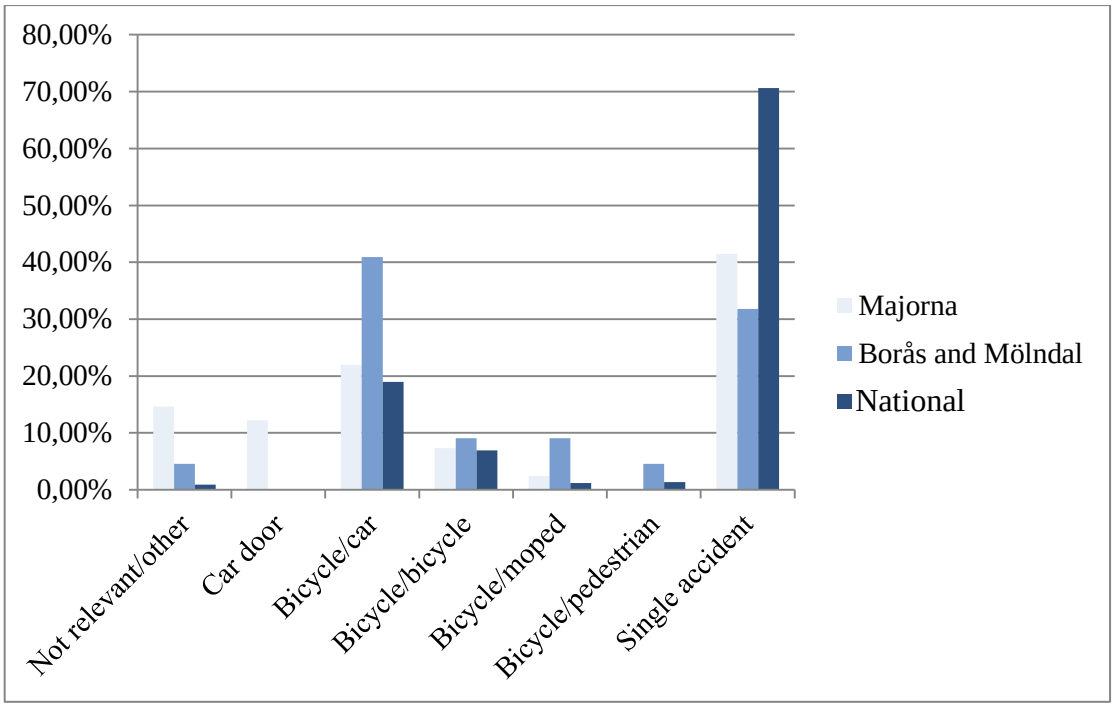


Figure 5 Type of severe and fatal bicycle accidents in Majorna (from STRADA), Borås and Mölndal (from STRADA) and in Sweden (from Niska et al, 2009)

Accidents with opening of car doors are considered a major problem in Majorna. In Borås and Mölndal there was not even one accident with opening of doors of motorized vehicles, and in the report by Niska et al (2009) it is not mentioned as a type of accident or even as an issue. It might be a problem but is not highlighted.

The proportion of severe and fatal bicycle accidents happening on pedestrian and bicycle paths is the same comparing Majorna and Borås and Mölndal, see Figure 6 below. The number of accidents in intersections and on streets differs largely, in Majorna the share is about the same whereas in Borås and Mölnal there are much more accidents in intersections than on streets. To make a fair comparison, the proportion of bicycles driving on bicycle paths and driving on the street should be evaluated.

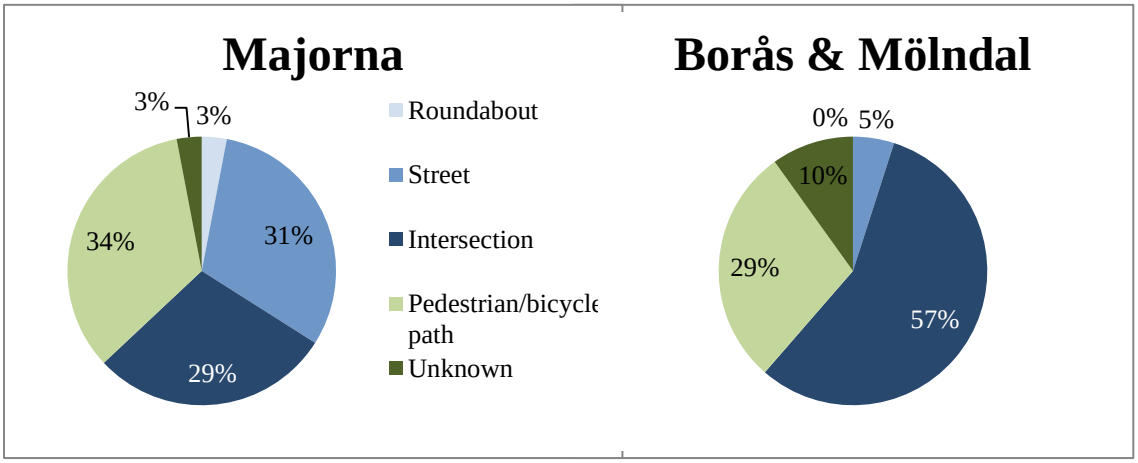


Figure 6 Location of the severe and fatal bicycle accidents in Majorna and in Borås and Mölndal (from STRADA).

4 Design of the Bicycle Priority Street

A road should be designed so that that the road users understand what kind of road it is, what the aim and the function of the road is and which behavior is expected from the driver (SWOV, 2010). This can for instance be shown by using the surface, the edge markings and the separations lines and by physical separations. This chapter highlights designs on Bicycle Priority Streets from other countries as well as recommended bicycle infrastructure in Sweden in order to, in Chapter 5, make recommendations of designs of Bicycle Priority Street that are suitable in Sweden.

4.1 Plan of the Street

To ensure a safe and comfortable street for the bicyclists, but also the motorists, it is essential to have sufficient space for the road users. At the same time, the width affects the speed; a wide road contributes to a higher speed than a narrow. It is important to compromise between these two qualities, and modifications of the surface of the plan can be done in order to change the visualization of the width and to make the plan look narrower than it actually is. The road users get the space they need, but at the same time the Bicycle Priority Street will work as intended. Note that the pedestrians are not included, as they are assumed to use the sidewalks.

4.1.1 Demands of the Road Users

This chapter focuses on the widths needed by different road users that could use the Bicycle Priority Street. There are recommendations, not requirements, for different space classes of the width distances on a local street in built-up areas in Trafikverket et al (2012b). The space classes are A, B and C (Trafikverket et al, 2012c):

- **Space class A:** Is considered to give a good objective safety and subjective safety/security for the road users as well as a good comfort for the road users. The road users do not have to adapt to other road users.
- **Space class B:** Is considered to give a less good comfort for the road users but a good objective safety and subjective safety/security if the road users adapt their speed to each other when meeting.
- **Space class C:** Is considered to give a low comfort for the road users but a good objective safety at low speeds. The measures recommended in space class C make the motorized vehicle drive on the opposite driving field when overtaking bicyclists and when two motorized vehicles meet a very low speed is needed.

The space classes mentioned above recommend different distances for a street with a speed limit of 30 km/h which are presented in Table 8 below. Hence 30 km/h is the highest speed recommended when mixing bicyclists and motorized vehicles. In addition to these distances there are some dimensions presented which are needed on a road with the speed limit of 50 km/h. This is in order to have the ability of calculate a normal width of a local street with this speed limit, since this is the kind of street that the Bicycle Priority Street might be implemented on. With this width a no change-scenario can be investigated.

Table 8 Recommended side distance in meter for the speeds 30 km/h and 50 km/h and different space classes.

		Space Class A	Space Class B	Space Class C
30 km/h (Trafikverket et al, 2012b)	Distance between moving bicycle and sidewalk	0,25	0,10	0,10
	Distance between moving car and the sidewalk	0,20	0,10	0,10
	Distance between moving truck and the sidewalk	0,20	0,10	0,10
	Distance between moving car and bicycle	0,40	0,20	0,20
	Distance between two moving cars	0,35	0,35	0,35
50 km/h (Vägverket et al, 2004)	Distance between moving car and sidewalk	0,40	0,20	
	Distance between two moving cars	0,70	0,50	
	Distance between a moving car and bicyclist	0,50	0,40	
	Distance between a moving bicyclist and sidewalk	0,25	0,10	

The width of a bicycle is assumed to be 0,75 meters (SKL, 2010). To ensure a good bicycle infrastructure an extra fescue dimension should be added, which can be seen in Table 9 below.

Table 9 Space needed by the bicyclists (SKL, 2010).

	Width (m)
Fescue dimension (v > 12 km/h)	0,5
Fescue dimension (v < 12 km/h)	0,8

The width of a motorized vehicle depends on what kind of motorized vehicle it is. In Table 10 below the widths of different motorized vehicles that could use the Bicycle Priority Street are mentioned. There should always be space for an exceptionally traffic situation for emergency traffic, like a fire truck, on a street (Trafikverket et al, 2012b).

Table 10 Widths of different motorized vehicles (Trafikverket et al, 2012c).

Type of motorized vehicle	Width (m)
Small car	1,66
Large car	1,78
Motorcycle and moped	0,7-1
Fire truck	2,55

4.1.2 Design of the Street Plan

How to design a Bicycle Priority Street differs between countries and the intensity of different road users. The four designs of the plan have been found and are brought up in this report:

1. Nothing further is made to the plan
2. Bicycle Priority Street with border strips
3. Bicycle Priority Street with a median
4. One-way street with suggestion lane for bicycles

The plan types are explained below:

1. Nothing further is made to the plan		

Figure 7 A Bicycle Priority Street in Münster, Germany, where nothing is made to the plan when making the street a Bicycle Priority Street (Photo: Sofie Johansson)

Design and idea	The motorized vehicles and the bicyclists use the same space. It can be used as two-way Bicycle Priority Street for both motorized vehicles and bicycles but also as a one-way Bicycle Priority Street for motorized vehicles and two-way for bicycles. It is used in Germany, the Netherlands and Linköping.	
Recommended widths	**Two-way Bicycle Priority Street for both motorized vehicles and bicycles**	In Germany nothing further is made to the plan when implementing the Bicycle Priority Street on the street, which makes it inexpensive to implement[9]. It is considered good to have such a narrow plan that two cars cannot meet without using for instance parking lanes on the sides since this function as a traffic calming measure. In the Netherlands the recommended widths on this kind of Bicycle Priority Street is 4,5 meters which gives space for two cars to meet and overtake bicyclists without disturbing them (CROW, 2007).
	One-way Bicycle Priority Street for motorized vehicles and two-way for bicycles	In Germany nothing further is made to the plan when implementing the Bicycle Priority Street, but it is required to have a minimum width of 3,5 meters[9]. In the Netherlands the recommend width is 3,85 – 4,85 meters which is considered to give enough space for a motorized vehicle and bicycle to meet (CROW, 2007).
Comment	In the Netherlands this design is only recommended on street with a very low intensity of motorized vehicles, <500 PCU/day (CROW, 2007).	

[9] Stephan Böhme (Traffic Engineer at the Municipality of Münster) interviewed by the authors March 13 2013.

2. Bicycle Priority Street with border strips	

Figure 8 A Bicycle Priority Street with border strips in Houten, the Netherlands (Photo: Sofie Johansson)

Design and idea	The design has a lane in the middle and border strips on the sides in another material (CROW, 2007). Both bicyclists and motorized vehicles use the lane in the middle (CROW, 2007). If an overtaking or meeting between motorized vehicles or bicyclists occurs, the motorized vehicle should use the border strips on the sides. This also implies a visual narrowing of the plan. This design is used in the Netherlands when there is a two-way Bicycle Priority Street for both motorized vehicles and bicycles and when the Bicycle Priority Street is one-way for motorized vehicles and two-way for bicycles.
Recommended widths	Recommended width of the lane is three meters which is considered to give enough space for bicyclists to meet and overtake (CROW, 2007). The total width is recommended to be 4,5 – 4,85 meters which is considered to give space for two cars to meet and for a motorized vehicle to overtake a bicyclist without disturbing the bicyclists. The border strips are recommended to have a maximum width of 0,75 meters each, as wider can make the bicyclists mistake them for bicycle lanes. They should also be in a different material than the lane in the middle and more uncomfortable surface for the bicyclist to ensure that the misunderstanding does not occur[10].
Comment	In the Netherlands this design is recommended on street with the intensity of <2000 PCU/day (CROW, 2007).

[10] Warner Beumer (Senior Traffic Designer at the Municipality of Rotterdam) interviewed by the authors March 15 2013.

3. Bicycle Priority Street with a median	

Figure 9 A Bicycle Priority Street with a median in Rotterdam, the Netherlands (Photo: Sofie Johansson).

Design and idea	The design has one lane in each direction which is separated by a median in the middle. Border strips on the sides can be used to enable a visual narrowing (BGSV, n.d). Each lane should be used by bicyclists and motorized vehicles in one direction[11]. If an overtaking by motorized vehicle takes place it should cross the median and use the opposite lane. This design is used in the Netherlands on two-way Bicycle Priority Street for both motorized vehicles and bicycles.
Recommended widths	Each lane is recommended to precisely fit a moving car, 2,10 meters (BGSV, n.d). The median should have a width wide enough to ensure that two motorized vehicles can meet with sufficient space between each other.
Comment	Medians reduce the accident rates in urban areas as long as they are not situated in curves (Elvik et al, 2009). The positive effect is gained since it increases the distance between the meeting vehicles, reduces the number of turning vehicles and makes it easier for pedestrians to cross the road. A curbed median is therefore safer than a median only marked in the pavement. When making the lane narrower the effects are not positive since it might cause accidents when crashing into them. This median would however only be visual and speed reducing and not an obstacle which has both pros and cons according to the factors just mentioned.

[11] Warner Beumer (Senior Traffic Designer at the Municipality of Rotterdam) interviewed by the authors March 15 2013.

4. One-way street with a suggestion lane for bicycles	
 **Figure 10 A one-way street with a suggestion lane for bicycles in Rotterdam, the Netherlands (Photo: Sofie Johansson).**	
Design and idea	In the Netherlands there are one-way streets for both motorized vehicles and bicycles which have a suggestion lane with even surface on the right side of the road, and a more uncomfortable surface on the left side[12]. This means that the street is more comfortable for the bicyclists than for the motorized vehicles, which demonstrates that the bicyclists are prioritized.
Recommended widths	The suggestion lane should be wide enough for one bicyclists comfortable bicycling[12]. If an overtaking between bicycles happens the overtaking bicyclist can use the area outside the suggestion lane. There should be space enough for motorized vehicle to overtake a bicyclist.
Comment	It is suitable to implemented on narrow one-way streets[12].

4.2 Surface

The bicycle is a two-wheeler and by that instable (SKL, 2010).The bicyclist needs to be the motor, balance on the two wheels, avoid unevenness and handle the traffic situation. This means that the bicyclist needs an even surface with good maintenance and area to maneuver on. Also the bicycle is not cushioned and for that the bicyclists need an even surface which makes the horizontal and vertical vibrations as small as possible. To ensure that the bicyclists use the lanes that are made for them the surface on these is recommended to be more even than on the surface next to it.

According to research in the Netherland the bicyclists prefer to drive on asphalt, followed by less even surface such as concrete tiles and cobblestones (CROW, 2007). Concrete tiles are rectangular cubes that are made concrete in the size of tiles and cobblestones are cubes chopped in stone, see Figure 11 on next page to visualize these surfaces. The bicyclists highly prefer a dense surfacing like asphalt and cement concrete because it offers great evenness and least resistance which makes it most comfortable. Modular paving generally retains its texture and skid resistance but has

[12] Stephan Böhme (Traffic Engineer at the Municipality of Münster) interviewed by the authors March 13 2013.

poorer evenness than closed surface. Also, surface like cobblestone, concrete tiles and other modular surfaces result in more noise when motorized vehicles drive on them compared to driving on asphalt (Vägverket, 2009). The cobblestone results in even more noise than concrete tiles and slabs when vehicles drive on them.

Figure 11 Examples of surface with concrete tiles to the left and cobblestones to the right (Photo: Helena Denvall).

Drainage is a factor that also affects the bicyclists highly (CROW, 2007). It is unpleasant to bicycle through big puddles and can even be dangerous since it can be impossible for the bicyclists to see the depth and form of the holes of the puddles. This can cause both dangerous maneuvers of the bicyclists and falls, thus potholes on the surface needs to be minimized by good maintenance in order to minimize single accidents.

A deviant color on the surface increases the attention and by that the traffic safety for the bicyclists (SKL, 2010). This measure is mainly considered in intersections in order to show the road users where they can expect bicyclists. When this is used in Sweden it is mostly the color red that is used. In the Netherlands red surface, mostly red asphalt, is used on most of the bicycle infrastructure[13]. Since red asphalt is used on almost all bicycle infrastructures this indicates continuity for the bicyclists and they easily understand where on the Bicycle Priority Street they should be located.

4.3 Parking

As could be seen in Chapter 3.2.2 parked cars are a traffic safety danger for the bicyclists. According to CROW (2007) it is advisable to minimize parked vehicles on Bicycle Priority Street since they are obstacles for the bicyclists and also a traffic safety danger considering opening of car doors. It is considered in the Netherlands that occasionally parked cars on the Bicycle Priority Street are not a problem because it is easy for the road users to pay attention to each other. Since most Bicycle Priority Street that exist today are in residential areas with many parked cars on the sides with no other place for them, solutions for safe parking is needed[14]. For example in the Netherlands, if more than 20 percent of the length of the Bicycle Priority Street is used for parking it is recommended to ensure safe parking with measures (CROW, 2007).

It is advised not to have perpendicular and diagonal parking on streets with bicyclists since this increases the risk of accident on the street remarkable when there are

[13] Herbert Tiemens (Traffic Expert at the Region of Utrecht) interviewed by the authors March 14 2013.

[14] Stephan Böhme (Traffic Engineer at the Municipality of Münster) interviewed by the authors March 13 2013.

bicyclists on the street (SKL, 2009). A transition from diagonal parking to parking parallel to the driving direction decreases the number of accidents with 35 percent, with no control of regression to the mean taken and all accidents included (Elvik et al, 2009). Parallel parking and loading places should always be on the right side of the area where the bicycles move, both when in mixed traffic and on bicycle lanes (SKL, 2010). This is to not disturb the bicycle traffic during loading and unloading of the parked vehicles. The parking is recommended to have a width of 2,75 meters to avoid accidents with openings car doors. According to Vägverket et al (2004), it is advisable to have 1,00 meter between a parked car and a bicycle to avoid accidents with open car doors.

When there is a parallel parking on the Bicycle Priority Street in the Netherlands it is advisable to use a safety strip between the traffic lane that the bicyclists use and the parking lane, see Figure 12 (CROW, 2007). The safety strip forms a buffer space for the safety of the bicyclists near parked vehicles. This safety strip should have a width of 0.5-0.75 meters to ensure a safe space and should be in a different surface than the bicycle infrastructure and the parking lane. This to ensure that the bicyclists will not use the safety strip, hence if the strip is too wide it could be mistaken to be a bicycle lane and the safety aspect disappears[15]. Other usage for the strip could be drainage (CROW, 2007).

Figure 12 Safety strip (Photo: Sofie Johansson).

On one-way Bicycle Priority Streets for motorized vehicles it is in the Netherlands considered to be the best option to have a diagonal parking, meaning that the parking lot should have 30 to 60 degree of parking angle from the main road (CROW, 2007). Then the motorized vehicle has to reverse into it and has a view of the street while reversing. Reversed parking is considered to make the street more bicycles friendly and the traffic safety problem of opening doors disappears at the same time as this option can fit more parking lots than parallel parking. This type of parking is safer than parallel parking since the driver can see the bicyclists on the street easier. To ensure room for parking maneuver the width of the carriageway plus the parking bay is recommended to be four meters or more.

4.4 Intersection

In the Netherlands it is preferred to give priority for the road users on the Bicycle Priority Street in intersections in order to prioritize the bicyclist network and make it more available and attractive for the bicyclists (CROW, 2007). It is however not permitted to implement priority on streets in residential areas but the legislators have made an exception for main bicycle routes. The drawdown of giving priority is that the Bicycle Priority Street can lead to higher speeds of the motorized vehicles and that the street gets too attractive, making the motorized vehicles use the Bicycle Priority

[15] Warner Beumer (Senior Traffic Designer at the Municipality of Rotterdam) interviewed by the authors March 15 2013.

Street instead of other roads, better adjusted for that traffic mode. If this is the case other measures to reduce the speed and attractiveness have to be made.

According to the traffic regulation in Germany it is the right hand priority rule that is applied in the intersections with one or two Bicycle Priority Street if nothing else is signed (ADFC, 2011). Priority might be arranged with other signs in intersections if it is reasonable (Schenk, 2013). Also in Germany it depends on how attractive the Bicycle Priority Street is for transit traffic, in order to not lead to high speeds and flows of motorized vehicles.

In Sweden, the bicycles do not have priority at crossings with motorized vehicles, but this can be regulated with signs and pictograms (SKL, 2010). The tendency for the motorized vehicles to give way to the unprotected road users' increases with reduced speed. The diagram that can be seen in Figure 13, presented by Hydén at Nordiskt Trafiksäkerhetsforum (2013), illustrates the interaction between motorists and bicyclists at bicycle passages depending on the motorized vehicles speed. It can be seen that the higher speed the motorized vehicle have the higher share of bicyclists give way and vice versa with lower speeds of the motorized vehicles. At a speed level of 30 km/h about 70 percent of the motorized vehicles give way to the bicyclists at a passage. Between the speed levels of 10-30 km/h about 75 percent of the motorized vehicles give way to the bicyclists.

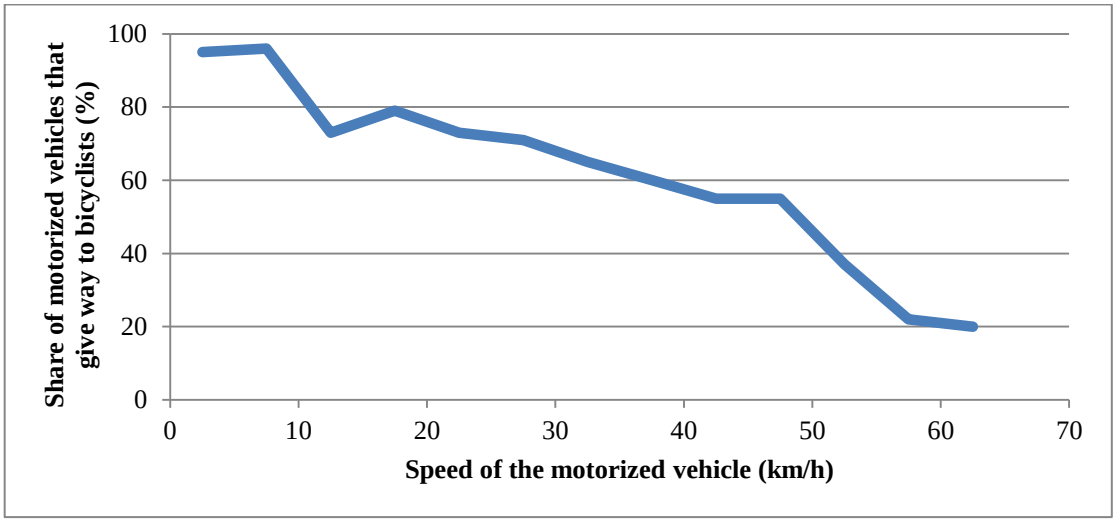


Figure 13 The share of motorists in different speeds which give way to bicyclists at bicycle passages (Hydén, 2013).

In Sweden pedestrians have priority at zebra crossings, a rule implemented in year 2000 (SKL, 2009). However, research and statistics have shown that this rule made the accessibility better for pedestrians, but not the safety. The probability of getting fatal injured at a zebra crossing is higher than crossing at a similar/equal passage not being a crossing. The experienced safety is lower at the latter example, making the pedestrian crossing the road more observant. Currently the option to give bicycles priority in intersections with motorized vehicles is discussed in Sweden in order to increase the bicyclists' availability (SOU, 2012).

When designing an intersection the aim is to have few conflict points and low speeds for all road users involved (CROW, 2007). The speed difference between cars and bicycles should be as low as possible, which means that the cars should drive in the speed of the bicycles, 15-20 km/h. In Sweden the recommended speed on unregulated crossings, to assure a safe environment, is set to 30 km/h with maximum 15 percent

exceeding it (SKL, 2009). To assure this it is essential to implement speed reducing facilities, just implementing a sign and new rules are not measures enough.

The design of an intersection has a large impact on the character of the connected streets, as well as the choice of routes in the area (SKL, 2010). When the flows are low on the roads the most common solution in an intersection is to use the right hand priority rule, when the motorized road users as well as the bicyclists give way to the vehicles coming from the right. Also having stops in all directions is considered a safe solution, but decreases the availability. It is also common to have one of the roads as a prioritized road, where the connecting roads have to give way or even stop when entering the main road. To turn a street into a main street makes the speed rice and increases the flows of the vehicles using the street as it is considered more attractive.

In an intersection the road user has the choice of turning or going straight forward. A crossing, on the other hand, is a place where some road users cross the street and continue on the other side. When a Bicycle Priority Street meets another road and continues on the other side of the road, it is something in between a crossing and an intersection, since the cars use it as an intersection while the most of the bicyclists continue straight ahead. The biggest issue regarding bicycles in intersections is turning cars and the bicycles going straight forward (SKL, 2009). It is better, from a traffic safety point of view, to integrate the bicycles with the cars in intersections than having separate bicycle paths. Other important measures in intersections are to have smooth surface so that no single accident occur, as these can have catastrophically consequences as well as a good visibility of the unprotected road users (SKL, 2010). To have pictograms showing that bicycles come from both directions increase the attention of the motorized vehicle.

An intersection can be design in several ways, and descriptions of several solutions where the bicycles are beneficial and a good traffic safety is aimed are described below.

Raised crossing: To raise the crossing/intersection on the intersecting road but keep the level constant on the Bicycle Priority Street reduces the speed of the motorized vehicles, which leads to both decreased probability and severity of an accident (SKL, 2010). The raised level also highlights the conflict area and therefore the attention of the motorized vehicles is increased (SKL, 2009). The experienced safety is therefore increased making the bicyclists less observant and careful (SKL, 2010). The motorized vehicles on the Bicycle Priority Street might take advantage of this increased availability. When raising the crossing the number of injured pedestrians is decreased with 50 percent and is assumed to be the same for the bicyclists.

Speed reducing facilities before crossing: To have a speed reducing measure before the crosswalk on the intersecting road makes the priority not obvious for the bicyclist which reduces the speed and increases the attention in the intersection (SKL, 2009). The mean speed for motorized vehicles when passing a speed bump is 20-25 km/h which reduces the number of total accidents with 35 to 70 percent.

Narrow crossing: To reduce the width of the intersecting road at the crossing forces the motorized vehicles to reduce the speed when passing the crossing and it also decreases the time needed for the bicycles to cross (SKL, 2010). This measure is not as efficient as speed bumps or raised crossing though, and making the street narrower with only markings is even less efficient and needs to be visible at all times (SKL, 2009).

If the road is too narrow, the motorized vehicle might concentrate of how to meet another motorized vehicle instead of focusing on the crossing. Therefore the crossing should either only fit one vehicle or make it possible for two cars to meet without any difficulties. With only one lane in the crossing the capacity for the motorized vehicles is remarkable reduced (SKL, 2010). This would also mean that it is difficult for heavy traffic to pass (SKL, 2009).

Traffic island: A traffic island is refuge between the driving lanes, making it possible to cross the road in two steps. It is recommended if the ability to cross the main road is low, when there are more than 800 PCU/hour (CROW, 2007). It needs to have a depth of 2,25 meters, which is not always possible due to available space (SKL, 2010). It demands a design in such a way that it is not an obstacle for the bicycles.

Colored crossings: To have another color on the surface in the intersection increases the attention of the motorized vehicles and then also the traffic safety (SKL, 2010). It gives the bicycles an obvious and notable place in the intersection/crossing, but can lead to mistaken safety if the bicyclists think they are more visible than they are. The effect of colored crossings is reduced when too many crossings are colored.

Signals: With high traffic flows, a suitable solution might be to implement signals in the intersection. This is a good solution for people with special demands, such as for children and people with visual impairment (SKL, 2009). With signals it is possible to have detectors prioritizing a preferred road user group. Also a green wave is a solution that might be suitable on the Bicycle Priority Street, meaning that the traffic signals on a route are designed and programmed to support the flow of the bicycles, so that if the bicycles keeps the speed of 20 to 25 km/h they will not get a red light.

Roundabouts: Another solution for situations with high traffic flow is roundabouts. The most suitable for bicycles in a traffic safety point of view is a roundabout with only one lane and when bicycles and motorized vehicles share the same space (SKL, 2010).

Flyover: A flyover is an intersection when the intersecting road is separated with different levels (SKL, 2010). As long as the flyover is designed so that it is used in the correct and natural way, and not making the road users take other passages due to an unpleasant crossing or detours, it is considered a safe way of crossing. This is however considered an expensive solution and is not profitable as a dense traffic measure.

4.5 Speed Reducing Facilities

Just implementing a Bicycle Priority Street with new rules and signs is not sufficient in order to assure a safe environment for the bicycles, since many vehicles exceed the speed limit. Generally, by lowering the speed limit with ten km/h, the actual speed level is reduced by three to four km/h, and with 20 km/h the effect is six to eight km/h (Nilsson, 2000). To have the unprotected road users using the same space as the motorized vehicles is only recommended when the speed is below 30 km/h, to assure a good standard for the bicycle (Vägverket et al, 2004). Several traffic calming measures are known to reduce the speed on a street.

On average, when implementing traffic calming measures the traffic at the local streets is reduced by 20-30 percent while the motorized traffic on the main web is only increased by one to five percent (SKL, 2009). In order to not make the traffic

have to take other routes in a too large extent it is better to reduce the speed at many places than to close streets. The accessibility remains but the availability gets reduced.

A narrow width of the street plan works as a speed reducer (SKL, 2009). The narrower the street plan is the slower the vehicles move if the width is smaller than seven meters. On the other hand, the narrower the street is less space exists to maneuver away from an unexpected event (CROW, 2007). To have a street with a maximum speed level of 30 km/h the street should have a maximum width of 3,5 meters which means that meeting places on the street are needed (SKL, 2009). If the Bicycle Priority Street is narrow enough it does not allow the motorized vehicles to overtake the bicyclists and the speed is ensured to be low (CROW, 2007). But only narrowing is usually not considered to be sufficient to keep the speed to 30 km/h and is suggested to be combined with other speed reducing facilities. The effect is lower if only visually narrowing by markings on the surface is used (SKL, 2009).

Speed reducing facilities do lower the speed level on the street and can also reduce the attractiveness of a Bicycle Priority Street for motorized vehicles even if there is right of way in intersections (CROW, 2007). The knowledge about how bicyclists and speed reducing facilities function is low and needs to be taken into account when discussing the facilities on the Bicycle Priority Street (SKL, 2010). But these should be designed so the bicyclists' availability does not get harmed and the winter maintenance can be proceeded well. Below some speed reducing facilities are presented.

Speed bumps: A speed bump is the speed reducing measure with the largest effect (SKL, 2009). In residential areas with the speed limit 30 km/h the accident rate decreases 27 percent when implementing a bump. The largest part of the decreased number is the accidents with the outcome of severe injuries and fatalities. To assure a maximum speed of 30 km/h it is recommended to have a speed bump every 30 meters. This would however have a large impact on the availability for the bicycles. It has been shown that the mean speed when passing a speed bump is 20-25 km/h. This reduces the number of total accidents with 35 to 70 percent depending on the speed before implementing the bump. Bumps do cause noise and vibrations when vehicles pass them and this should be taken into account when deciding on implementing these on a street (CROW, 2007). In addition, speed bumps decrease the accessibility for public transport and emergency services (SKL, 2009). They also make the maintenance difficult and decrease the standard on the road which can cause more single accidents for bicyclists (Göteborgs Stad 2009).

To prioritize the availability for bicyclists a speed bump with a bypass with a comfortable width for the bicyclists can be installed (SKL, 2010). This can be made by using a road pillow-bump shown in Figure 14 (SKL, 2009). Another solution is to use a sinus shaped speed bump, called the Wattska-bump, with a circular profile, and reduce the heights at the sides (SKL, 2010).

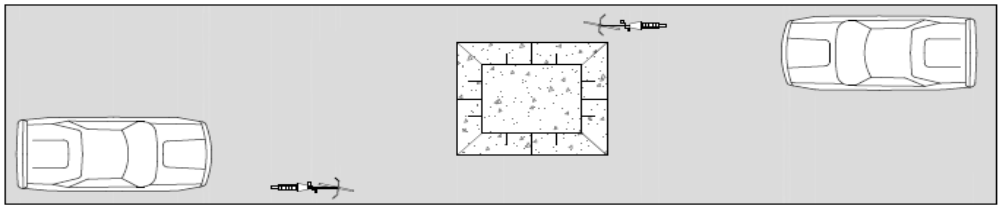


Figure 14 A road pillow with a bypass for the bicyclists which gives space for the bicyclists to pass the bump without going over it

Narrowing by using narrow sections: To occasionally make the street even narrower is a speed reducing facility (SKL, 2010). The sections should be narrow enough not to allow two motorized vehicles to meet in the section.

If narrowing is used on a street with bicycles, it is by SKL (2010) recommended to design it with a bypass for the bicycles to ensure that the bicyclists do not get crushed between the facility and motorized vehicles, as in the example in Figure 14 on the previous page. This solution also gives a straight line for the bicyclists to bicycle on. Before and after the narrowing, parking should be forbidden 10-15 meters because it would reduce the accessibility on the bypass. The bypass should have a comfortable width for the bicyclist. The disadvantage of this is that the bypass is hard to winter maintain and often gather a lot of snow and ice which forces the bicyclists to use the narrowing. This can cause more single accidents (Göteborg Stad, 2009).

Narrowing by shifting the street: Shifting the street and by that make it narrower is another way to keep the speed level low. To make the street turn even though it is not essential forces the road users to reduce the speed and deletes the feeling of a headway and possibility of accelerate (SKL, 2009). The effect on traffic safety is positive as long as the visibility is not broken. The first hinder that the road user focuses should be located on the right hand side. One drawdown of this solution is that the maintenance is difficult and if it is not made properly it can cause single accidents (Göteborg Stad, 2009).

Speed cameras: Speed cameras have, according to several investigations, shown to have a good speed reducing effect (SKL, 2009). The speed camera is a camera locker with radar inside that reads the vehicles´ speed in a certain point. If the speed of the vehicle is larger than the speed limit a photo of the vehicle is taken, the registration number and the driver of the vehicle and is later sent to the police. Speed cameras should be located on crash safe poles and should be indicated with a traffic sign which shows that automatic surveillance is occurring.

A drawdown of speed cameras is that motorists drive in uneven speeds on the streets; they break before camera and accelerate after (SKL, 2009). In Sweden it is, in urban areas, not considered to be a cost efficient speed reducing measure since there are other speed reducing measures that are cheaper and easy to implement in urban areas and the layout of the speed camera can be perceived as ugly.

Pre- and after measurements have been conducted on a speed camera located at a zebra crossing in Umeå (Umeå kommun, 2000). The measures show that the speed camera gives a little bit better effect in reducing the speed to 30 km/h than the road pillow bump, which was located there before.

Noise strips: Noise strips are small elevations going transvers the street that make noises when crossing (SKL, 2009). It does not directly decrease the speed but makes the road user more observant on other road users. It can however cause noise and vibrations from the motorized vehicles that might disturb the surrounding environment and might increase the probability of single accidents for the bicyclists if they are slippery.

4.6 Sign and Pictogram

It is important to show the road users that they are located on a Bicycle Priority Street and different signs are used in different countries. In Linköping, Sweden, there is a sign recommending the speed 20 km/h on the Bicycle Priority Street together with an

extra sign saying Cykelfartsgata, Bicycle Speed Street in Swedish, see Figure 15 below[16].

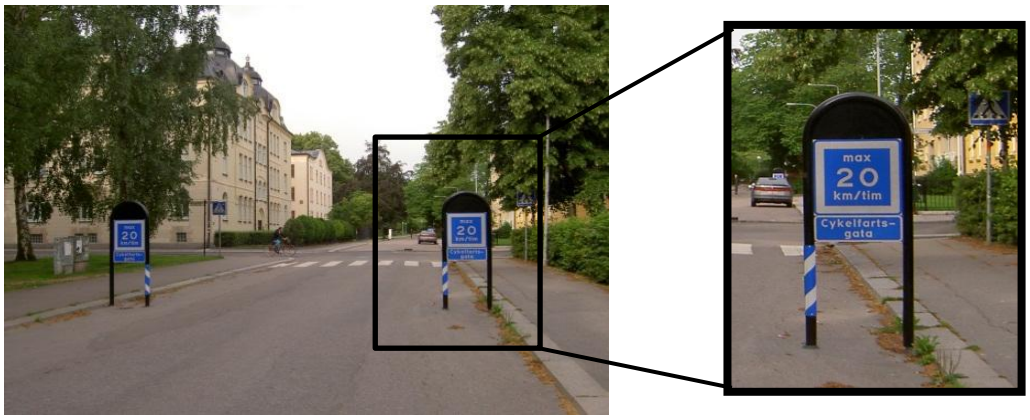


Figure 15 The road signs on the streets that have the function of a Bicycle Priority Street in the municipality of Linköping today (Hahn, 2013).

In Germany the signs used on the Bicycle Priority Street are included in the traffic regulation (StVO, Anlage 2, ifd Nr23). Two signs are used in the beginning of the Bicycle Priority Street, one that says it is a street for bicycles and one that explains which other traffic that is allowed on the street, which can vary (Schenk, 2013). The signs can be seen in Figure 16 below, where also the sign used at the exits of the Bicycle Priority Street can be seen.

The sign used on the Bicycle Priority Street in Belgium is also included in the traffic regulation; see Figure 16 (Belgisch Staatblad, 2012). It is similar to the most common sign used in the Netherlands; see Figure 16. The sign says that it is a bicycle path where the car is a guest. Since the Bicycle Priority Street is not included in the Dutch traffic regulations no single sign is recommended and several of them exist.

Figure 16 From left: The sign entering a Bicycle Priority Street in Germany (Photo: Sofie Johansson), the sign exiting a Bicycle Priority Street in Germany (Photo: Sofie Johansson), the most common sign used on Bicycle Priority Street in the Netherlands (Photo: Helena Denvall) and the sign on the right is the one used in Belgium (Belgisch Staatsblad, 2012).

In addition to signs that tell the road users they are located on a Bicycle Priority Street, pictograms can be used. They have a function of reminding the road users what the street are used for and increase the attention of mainly the motorists (SKL, 2010). In Sweden it is advised to have pictograms of bicycles every 25th meter on bicycle lanes where the traffic environment is complicated and on every 50th-100 meter in less

[16] Hahn, P-E (2013-02-26) *Cykelfartsgator* [Bicycle speed streets. In Swedish]. Personal mail contact with S. Johansson (sofiejo@student.chalmers.se) .

complicated traffic environments. It is especially advisable to have pictograms of bicycles in the beginning of bicycle paths and after crossings.

In Germany pictograms are commonly used on the Bicycle Priority Streets but they change in design[17]. For instance, in Münster the pictogram that can be seen in Figure 17 is used. This is considered to be visible and enlighten the road users that they are using a Bicycle Priority Street. In the Netherlands pictograms are used to some extent but are considered to be expensive to maintain and cannot be seen when there is snow or leafs on the ground (Tiemens, 2013). When pictograms are used they are similar to the picture used on the sign.

Figure 17 Example of the pictogram used in Münster, Germany (Photo: Sofie Johansson).

[17] Stephan Böhme (Traffic Engineer at the Municipality of Münster) interviewed by the authors March 13 2013.

5 Recommendation for the Bicycle Priority Street

To ensure that the Bicycle Priority Street is used as it is supposed to and achieves its function, the design is essential. The aim of the street and the bicyclist's new priority in the infrastructure must be obvious as it is a new situation on the Swedish roads and for all the road users. In order to reach the goal of the Vision Zero and to improve the bicyclist's situation and status, this new type of road must contribute to an improved safety. In Chapter 2, 3 and 4 integrated traffic solutions, bicyclists' traffic safety situation and the state or research regarding Bicycle Priority Street has been presented. This background, with problems and solutions in the bicycle infrastructure, is in this chapter discussed and outcomes with recommendations of how and where to construct a Bicycle Priority Street that creates a safe and sustainable infrastructure adjusted for the bicyclists. This chapter gives recommendations regarding its *function, intensity, speed, plan, surface, parking, intersection, speed reducing facilities* and *sign and pictogram.*

5.1 Function

The definition of a Bicycle Priority Street should be that it is a bicycle street where motorized vehicles are allowed on the permission of the bicycles. The reasons for implementing Bicycle Priority Streets are several, the most important are;

- It works as a missing link and fulfills the bicycle network
- It is a solution for dense areas
- It increases the availability for bicyclists and shows that they are prioritized which increases the number of bicyclists

A Bicycle Priority Street has however other positive effects on the infrastructure, which are mentioned bellow;

- It reduces the availability and attractiveness for the motorized vehicles but not the accessibility; the points of interests are still reachable, but not as fast as before. It does however give the motorized vehicles improved accessibility than converting it into a bicycle path/street.
- Encourages interaction between the different road users
- Makes the motorists show more respect to the bicyclists
- It has a traffic calming affect
- It contributes to a positive change of the urban space
- It improves the environment
- It gathers the bicyclists in an area to the Bicycle Priority Street
- It enables more bicycling side by side
- It does not demand much reconstruction and is considered an economical measure

The latter effect is considered important on the behalf of municipalities. For the municipalities considering implementing a Bicycle Priority Street as a tryout, this was one of the main reasons for doing it. Costs are not discussed in this report but in the Chapter 5.4 the different plan types are compared regarding the scope of the reconstruction needed.

Based on the reasons above, the location of a Bicycle Priority Street should be on a missing link in a dense area and attract the bicyclists in that area to use the Bicycle Priority Street instead of parallel streets. It is therefore not recommended to implement this on several streets in an area.

In Sweden it is today allowed to bicycle side by side as long as it does not hinder or endanger other road users. A Bicycle Priority Street would increase the space and prioritize the bicycles and therefore enable more bicycling side by side. This enables more social bicycling which improves the attractiveness of this traffic mode.

The study of the most common accidents with bicyclists where the outcome is either severe of fatal shows that single accidents together with accidents with motorized vehicles are the most common. According to the accident study in Majorna, those two types have the same share but the study made by Niska et al (2009) got the result of twice as many single accidents than accidents with motorized vehicles. There are however more single accidents on the road compared to the bicycle path. Of the single accidents happening because of bad maintenance of the surface like snow and gravel, it is more common that they happen on the bicycle path than on the street or the crossing. This might be due to that the surface on the road is better and the maintenance is improved compared to the bicycle path. In many municipalities, the infrastructure for the motorized vehicles is often prioritized compared to the one for bicyclists and pedestrians.

It is also concluded that more accidents happen on street than on bicycle paths, and streets in built up areas with a speed limit of 50 km/h are the ones with the most accidents with injured bicyclists. To make a fair comparison, the proportion of bicycles driving on bicycle paths and driving on the street should be evaluated. Also crossings are dangerous; this is where most of the accidents between bicycles and motorized vehicles happen. It can be concluded that these streets and crossings need to be reconstructed to improve the traffic safety.

5.2 Intensity

It is in all countries where Bicycle Priority Streets are implemented required to have more bicyclists than motorized vehicles using the street, in the Netherlands there should be twice as many bicyclists. This is to ensure that the bicyclists are dominating and to show that they are the prioritized road users. The situation of having more bicycles than motorized vehicles is considered sufficient since this has worked in Germany and Linköping. One of the aims of the Bicycle Priority Street is to attract bicyclists; both from surrounding streets but also people that earlier used motorized vehicles. This means that the Bicycle Priority Street does not need bicyclists as the dominating traffic mode before the implementation but it is recommended to have when it is in use. The behavior of the road users' change with many bicycles, they show respect and keep a low speed.

In the Netherlands and Germany there is a maximum flow of 2000-3000 motorized vehicles per day using the Bicycle Priority Street. This is also a requirement to be fulfilled when the Bicycle Priority Street is implemented and does not need to be the situation before.

In Figure 18 on next page, recommendations on what bicycle infrastructure that is suitable at certain intensities of motorized vehicles and bicycles on a street is presented. The diagram is made from the data that can be seen in Chapter 2.2.2. The safety for bicyclists is increasing when there are 50 bicyclists or more on a mixed traffic street per hour, which means 1200 bicyclists per day. Hence this number of bicyclists has been taken as the recommended minimum intensity of bicycles on a Bicycle Priority Street. The highest amount of motorized vehicles that are recommended is a mean value of the Dutch and German number, 2500 motorized

vehicles per day. When a Bicycle Priority Street is recommended the intensities are such that the interaction between the road users would work for a properly functioning Bicycle Priority Street.

When mixed traffic is recommended it is because the intensity of motorized vehicles is so low that an implementation of a Bicycle Priority Street is not considered motivated. When separation is recommended the intensities of the road users are of such high levels that interaction between different road users would not work properly for a functioning Bicycle Priority Street.

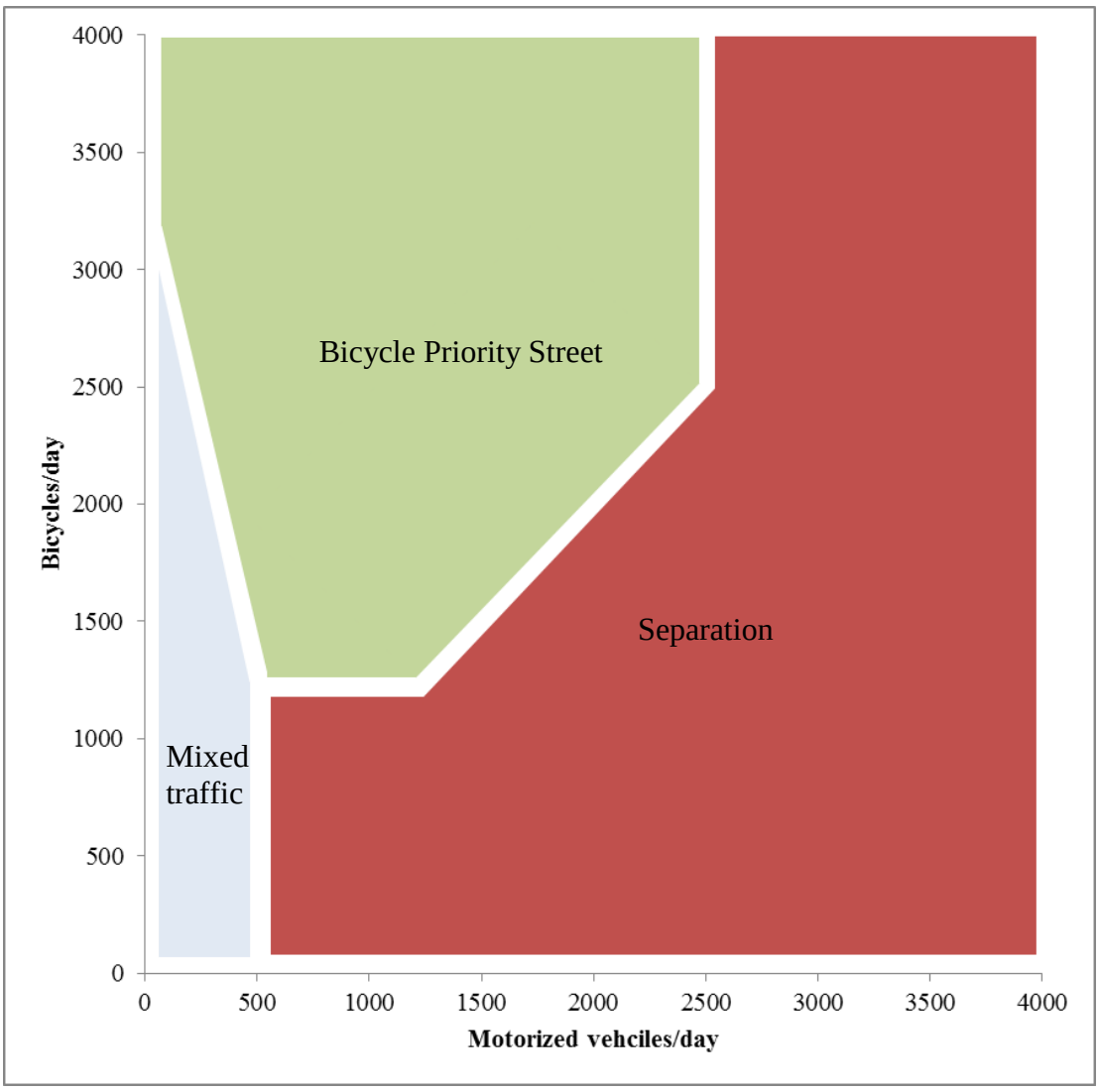


Figure 18 What bicycle infrastructure to implement at certain intensities of bicycles and motorised vehicles on a street per day.

In Germany and the Netherlands, where the Bicycle Priority Street is commonly used today, the share of bicyclists is remarkably higher than in Sweden. To have 1200 bicyclists per day on the Bicycle Priority Street might today not be realistic to achieve in a Swedish city, especially not during winter season and hours outside peak hours. Because of this, a design on the Bicycle Priority Street showing the bicyclists priority, a low flow of motorized vehicles and to assure that the bicyclists is the dominating traffic mode is even more important in Sweden. However, hopefully a Bicycle Priority Street is one step towards an infrastructure increasing the bicyclist status and attracts more bicyclists. That countries such as Denmark, the Netherlands and Germany have much higher bicycle shares initiates that it is possible to achieve.

5.3 Speed Limit

In the countries using Bicycle Priority Streets today, 30 km/h is the speed limit mostly set on the road. In the tryout in Linköping, 20 km/h was used. On pedestrian streets the speed limit is walking speed which is considered to be seven km/h, another option of a speed limit could be the corresponding speed for bicycles, meaning that the motorized vehicles are not allowed to drive faster than the bicycles. Bicyclists drive in different speeds depending on their physical health, the conditions of the road, the aim of the trip and other factors impacting the situation, but the mean speed of bicycles is said to be 15 to 20 km/h and it is recommended to dimension for 16 km/h.

In the evaluations of interaction between bicyclists and motorized vehicles and their speed level it can be seen that the speed of the motorized vehicles has big impact on the interactions between the two road users. Below, in Figure 19, the results from two evaluations can be seen. The lower the speed level the better interaction on the bicyclist conditions can be concluded, which is the wanted situation on the Bicycle Priority Street. At bicycle passages the tendency of motorists to give way to bicyclists is larger than on shared space. The reasons for this have not been found. It is important to show the intended traffic behavior with the design on the Bicycle Priority Street and not only focus on speed level although it is the main aspect to work with for a Bicycle Priority Street to work as intended.

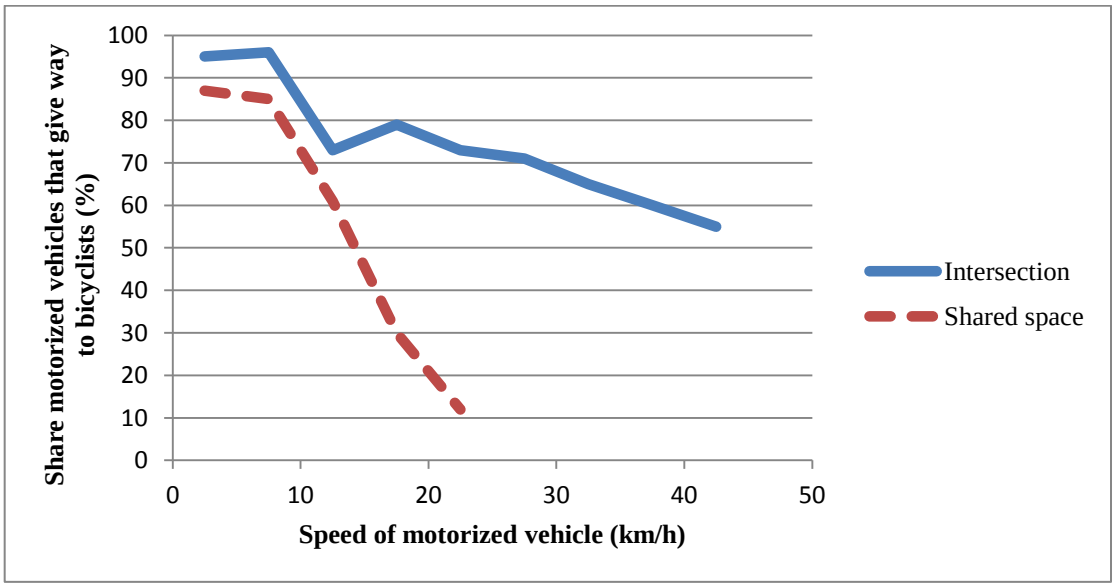


Figure 19 Share of motorists that prioritize the bicyclists at intersections and at shared space (from Tyréns (2007) and Hydén (2013).

To evaluate whether 30 km/h, 20 km/h or bicycle speed is the most suitable speed on a Bicycle Priority Street, a so called SWOT analysis has been conducted which can be seen in Table 11. The Strengths, Weaknesses, Opportunities and Threats of the different options have then been evaluated. The information from Chapter 2, 3 and 4 lay as basic for the arguments mentioned, and also a group of expertise has given inputs to make the evaluation absolute.

Table 11 SWOT-analysis of Bicycle Priority Street with the speed limits 30, 20 km/h and bicycle speed. The prefix explains different qualities.

Traffic safety | Subjective safety/security | § Potential | Environmental effects | Traffic generating | Interaction

	30 km/h	20 km/h	Bicycle speed
Strength		Less severe consequences when a collision Low probability of a collision Shows that the speed is adjusted to be as the bicyclists Motorized vehicles allowed to overtake → will be an interaction	Less severe consequences when a collision Low probability of a collision A new concept contributing to an increased attention The speed is on the conditions of the bicyclists No overtaking allowed → on the conditions of the bicyclists
	§ The speed with most probability of being kept		
		Enables an interaction between the traffic modes	Demands a positive interaction between the traffic modes
Weakness	One out of ten dies when in an accident The speed limit is higher than the mean speed of the bicyclists Risk of bicyclists getting overtaken often Not on the conditions of the bicyclist; not their speed and overtaking is allowed The motorized vehicles are the dominating road users Low possibility of interaction between the modes	Hard to keep the speed Too low speed for some bicyclists	Bicyclist might get stressed due to being the dimensioned road user Problems in slopes
Opportunity	§ No large changes in traffic regulations	Decreased motorized traffic Improved environment	Decreased motorized traffic Improved environment § New way of thinking, creating an infrastructure dimensioned for bicyclists
Threat		§ Hard to implement with the current traffic regulations § Might be lack of respect of the speed limit § Decreased accessibility for motorized vehicles § Risk of only being a recommended speed of 20 km/h	How is the situation without bicyclists on the road? § What is bicycle speed? § Large change in traffic regulations § Decreased availability for motorized vehicles

As can be seen in the SWOT analysis the option with 30 km/h has the most weaknesses, since it does not fulfill the goal of making the bicyclists the prioritized road users. Neither is the traffic safety satisfying but it is at the same time the easiest option to implement with the current traffic regulations in Sweden. To implement 20 km/h and bicycle speed does have several threats since it is a big change in the regulation. In Linköping it was not allowed to continue using the speed limit of 20 km/h, since this speed limit does not exist today and the infrastructure should have homogenous speed limits that are followed by the road users. But both 20 km/h and bicycle speed have more strengths and fewer weaknesses. To have bicycle speed on the Bicycle Priority Street demonstrates that the road is created for the bicycles, which is what the Bicycle Priority Street really is about.

The Bicycle Priority Street is profitable for different kind of road users which is important to take into account when implementing it. A so called value rose is used in order to evaluate for which kind of bicycle groups a Bicycle Priority Street is beneficial. A value rose is a tool for visually showing different effects between some alternatives, here the attractiveness for different type of bicyclists on the speed alternatives *30 km/h*, *20 km/h* and *bicycle speed*, see Figure 20 below. Disabled bicyclists are not taken into account since they are few.

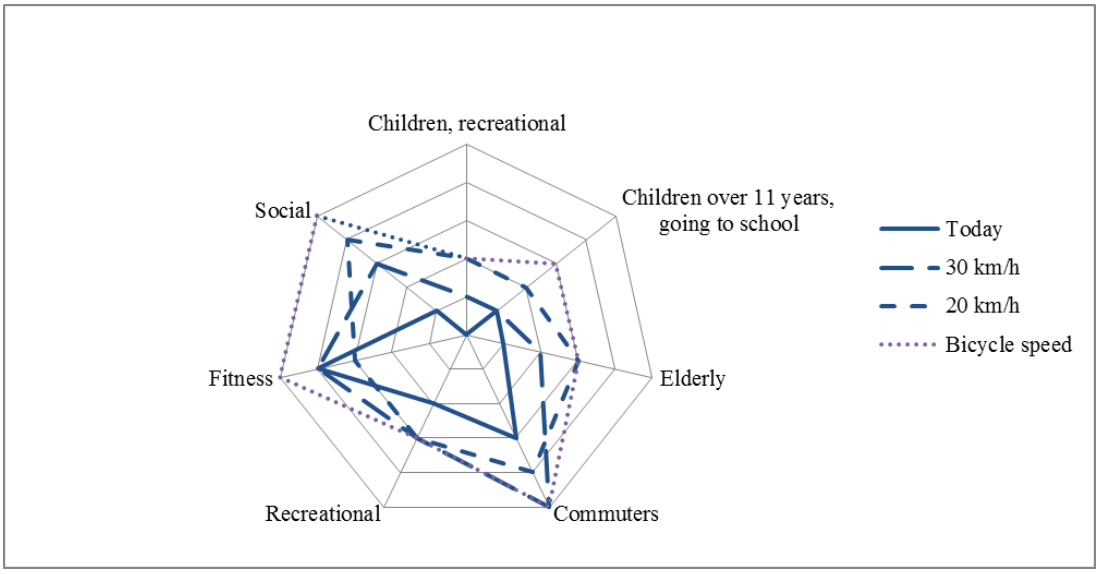


Figure 20 Attraction of the Bicycle Priority Street for different bicycle types.

Children using the road as recreational bicycling and children going to school are two types of bicycle groups. Today most parents do not feel comfortable letting their children bicycle on local streets with mixed traffic since children are not able to handle the surrounding traffic like older road users. On a Bicycle Priority Street the motorized vehicle has to show more respect to the bicyclists and the street is designed to make the motorists obey this and making the road more suitable for children.

Elderly are not comfortable bicycling in mixed traffic since it is a bicycle group with low speed and in need of a big fescue space that easily get stressed and pushed away by the motorized vehicles. On a Bicycle Priority Street the motorized vehicle shows them more respect.

Commuters prefer a good availability and rather high speeds and possibility to overtake each other, why 20 km/h might be too slow. A Bicycle Priority Street

completes missing links in their daily trips, and is designed for their needs on streets where they earlier had to drive on the permissions of the motorized vehicles.

The recreational bicyclist does not like to drive on the local streets and to share space with the motorists. On a Bicycle Priority Street they still have to share space with the motorists but more on their own conditions than today.

Bicyclists using the trip for fitness use local streets more than bicycle paths since the speed correspond better to their needs. On the other hand they can easily bicycle in a higher speed than 30 km/h and their availability is then decreased by a Bicycle Priority Street.

Social bicyclists are driving side by side and talking while they drive their bicycles. Not being pushed to the side and to be able to choose the speed are factors important for this bicycle group.

The speed limits on the Bicycle Priority Streets create different kind of Bicycle Priority Streets, and the bicycle types mentioned above prefer different speeds. Before implementing a Bicycle Priority Street in Sweden and in the Swedish traffic regulation it has to be considered why it is implemented and for whom. It is important to make a consistent system in the whole country so that the road users know the aim of the road.

5.4 Plan of the Street

One of the functions of the Bicycle Priority Street is to improve the bicyclists infrastructure. Therefore should the conditions for the bicyclists on the Bicycle Priority Street be as favorable for the bicyclists as possible. The bicyclists should never have to use uncomfortable surface. The accessibility for the motorists should however be remained, but the comfort can be reduced in such way that they understand that the bicyclists is the prioritized road user.

Three different types of streets are evaluated;

- One-way Bicycle Priority Street for both motorized vehicles and bicycles
- One-way Bicycle Priority Street for motorized vehicles and two-way for bicycles
- Two-way Bicycle Priority Street for both motorized vehicles and bicycles

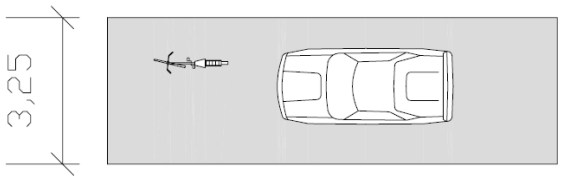
Different plan types have been created as possible designs for the Bicycle Priority Street. These have been developed by using inspiration from the Netherlands, Germany and other solutions in bicycle infrastructure and by combining favorable components. The plan types have then been evaluated regarding the factors *character of the street, environment, subjective safety/security, traffic safety, effects on infrastructure* and *economy*. The factor traffic safety is only estimated, a more thorough evaluation is conducted in Chapter 6 and 7. The alternatives have been given grades in the scale of Excellent, Acceptable and Unacceptable according to how they are correlated to the factors. They are also compared to the situation today and an option of not changing the design of the street and only implement new rules and sign. In Appendix II the tables with motivations are presented and in the report the preferred and most appropriate alternatives are demonstrated. The method of evaluation has taken inspiration from Boverket et al (2004) and SKL (1998), both handbooks in traffic planning.

When choosing dimensions for the bicyclist´s space the dimensions from Trafikverket et al (2012b) for Space Class A are used since these are the road users that are prioritized on the Bicycle Priority Street. The motorized vehicle should use the Bicycle Priority Street restrictively and on the bicyclist's conditions with low speeds and therefore dimensions for Space Class C are used for the motorist's space. The measures in space class C make the motorized vehicle drive on the opposite driving field when overtaking bicyclists and when two motorized vehicles meet a very low speed is needed, which is desired at the Bicycle Priority Street. When medians and border strips are used in the plan types, the aim is to design them in such way that the bicyclists do not use them since the aim is that they are used by the motorized vehicles. The calculations and the motivations for the widths in the different plan types can be seen in Appendix III.

One-way Bicycle Priority Street for both motorized vehicles and bicycles

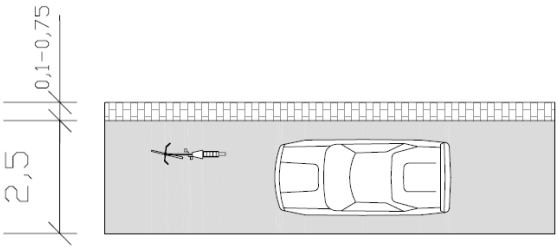
Today

The street is an ordinary local street with mixed traffic. There is space for bicyclists to overtake each other but there is no comfortable space for motorized vehicles to overtake the bicycles. The speed is 30 or 50 km/h.



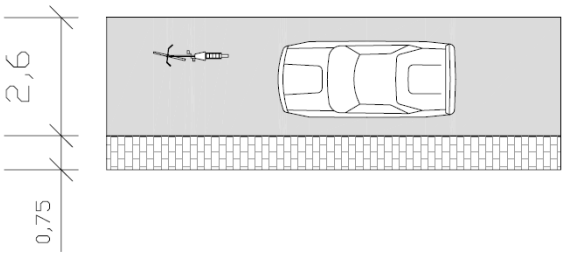
Border strip on right side

The street has a border strip on right side of the road which gives an impression of a narrower road. The bicycles and motorized vehicles drive on the left side of the border strip, and there is no space for cars to overtake bicycles unless the bicycles use the border strip. There is however enough space for bicyclists to overtake each other.



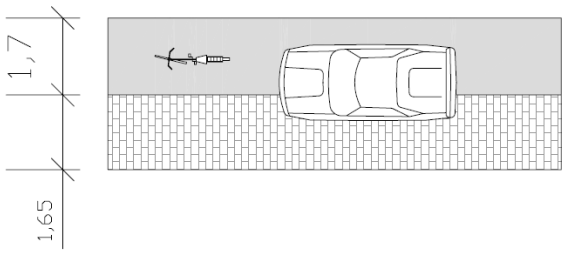
Border strip on left side

The street has a border strip on the left side and both the motorized vehicles and bicycles drive on the right side of the strip. If the motorized vehicle wants to overtake the bicycle it has to use the border strip on the left. If a bicycle overtakes another bicycle it does not have to use the border strip.



Wide border strip on left side

The street has a wide border strip on the left side and the motorized vehicle does always have two wheels on the border strip. The bicycle drives on the right side of the strip, so that the bicycle has a smooth surface, but when overtaking other bicycles it has to use the border strip. The motorized vehicle does always have an unsmooth surface, not only when overtaking.



Not changing the design of the plan is, according to Table 12 below, an unacceptable option. How the other options have been graded can be seen in the same table.

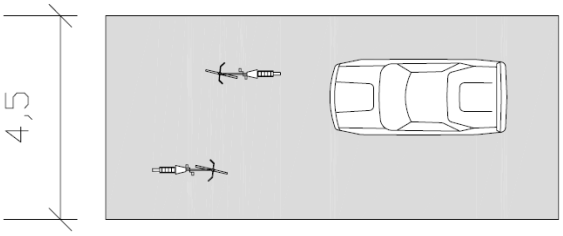
Table 12 Grading of the plan type option *One-way Bicycle Priority Street for both motorized vehicles and bicycles.*

Criteria	Today	Border strip on right side	Border strip on left side	Wide border strip on left side	Nothing is made to the plan
Character of the street	Acceptable	Acceptable	Excellent	Excellent	Acceptable
Environment	Acceptable	Excellent	Excellent	Acceptable	Acceptable
Subjective safety/security	Acceptable	Excellent	Excellent	Excellent	Acceptable
Traffic safety	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
Influence on modal split	Unacceptable	Excellent	Excellent	Acceptable	Unacceptable
Economy	Investment low	Investment higher	Investment higher	Investment highest	Investment low
	Maintenance low	Maintenance higher	Maintenance higher	Maintenance highest	Maintenance higher

One-way Bicycle Priority Street for motorized vehicles and two-way for bicycles

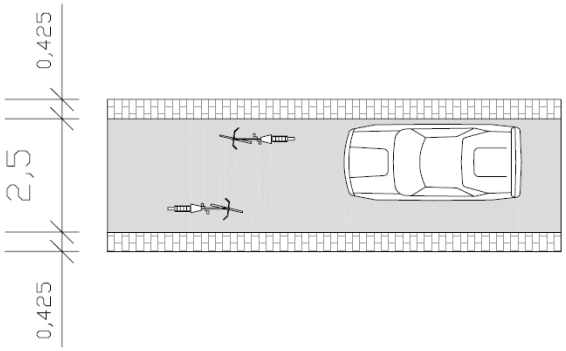
Today

The street is an ordinary local street with mixed traffic. There is both enough space for bicyclists to overtake each other and for motorized vehicles to overtake the bicycles. The speed is 30 or 50 km/h. A street with one-way traffic for cars but two-way for bicycles today often has a comfortable space allowing one motorized vehicle and one bicycle to meet. The width is therefore the same as the street with two-way traffic for both the cars and the bicycles.



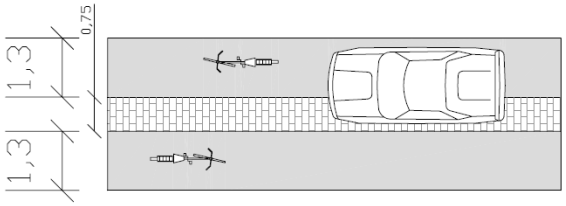
Border strip on both sides

This option has border strips on both sides of the road. If the motorized vehicle overtakes a bicycle it can use the left hand border strip, and when it meets a bicyclist it can drive on the right border strip in order to give the bicycle more space. It does also enable comfortable overtaking between bicycles.



Bicycle paths on both sides, median in middle

In this option the motorized vehicle drives with one wheel on the border strip/median and one on the right bicycle path. In order to overtake a bicycle it has to use the left/meeting bicycle path. It does not enable comfortable overtaking between bicycles since one of them has to use the median.



All options have the grade Acceptable regarding traffic safety as can be seen in Table 13 below. As earlier mentioned this factor is just estimated and a more thorough evaluation is conducted in Chapter 6 and 7.

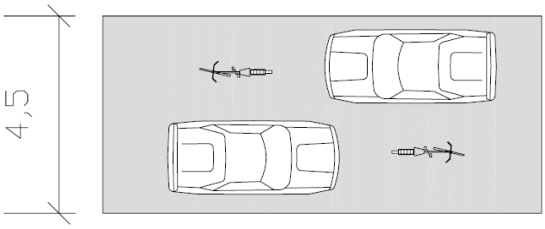
Table 13 Grading of the plan type option *One-way Bicycle Priority Street for motorized vehicles and two-way for bicycles.*

Criteria	Today	Border strip	Median	Nothing is made to the plan
Character of the street	Acceptable	Excellent	Excellent	Acceptable
Environment	Acceptable	Excellent	Excellent	Acceptable
Subjective safety/security	Acceptable	Excellent	Excellent	Acceptable
Traffic safety	Acceptable	Acceptable	Acceptable	Acceptable
Influence on modal split	Unacceptable	Excellent	Acceptable	Unacceptable
Economy	Investment low	Investment highest	Investment highest	Investment low
	Maintenance low	Maintenance higher	Maintenance highest	Maintenance higher

Two-way Bicycle Priority Street for both motorized vehicles and bicycles

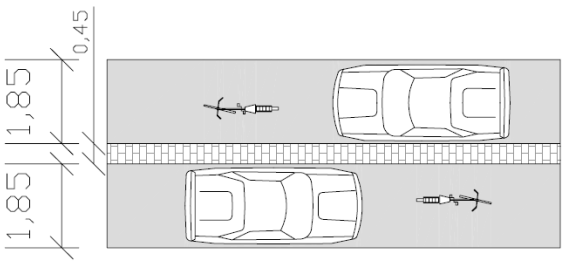
Today

The street is an ordinary local street with mixed traffic. There is both sufficient space for bicyclists to overtake each other and for motorized vehicles to overtake the bicycles. The speed is 30 or 50 km/h.



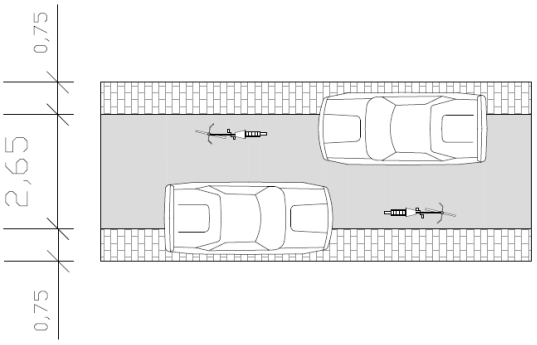
Wide median

In this option the motorized vehicle drives with one wheel on the border strip and one on the bicycle path. In order to overtake a bicycle it has to use the meeting lane. It does not enable comfortable overtaking between bicycles since one of them has to use the median.



Narrow lane with border strips on both sides

In this option the motorized vehicle drives on the border strip when meeting another motorized vehicle, and when overtaking a bicycle they both fit on the main lane. It also enables comfortable overtaking between bicycles.



In the criteria influence on modal split the options *today* and *nothing is made to the plan* are considered unacceptable, compared to the options *wide median* and *narrow lane with border strips on both sides* which have an excellent quality, as can be seen in Table 14 below. As earlier mentioned, to see how the criteria and options are graded se Appendix II.

Table 14 Grading of the plan type option *Two-way Bicycle Priority Street for both motorized vehicles and bicycles.*

Criteria	Today	Median	Border strip	Nothing is made to the plan
Character of the street	Acceptable	Excellent	Excellent	Acceptable
Environment	Acceptable	Excellent	Excellent	Acceptable
Subjective safety/security	Acceptable	Excellent	Excellent	Acceptable
Traffic safety	Acceptable	Acceptable	Acceptable	Acceptable
Influence on modal split	Unacceptable	Acceptable	Excellent	Unacceptable
Economy	Investment low	Investment higher	Investment highest	Investment low
	Maintenance low	Maintenance highest	Maintenance highest	Maintenance higher

Looking at the Tables 12-14 it can be concluded that for a Bicycle Priority Street with one-way traffic for both motorized vehicles and bicycles it is the plan type *border strip on the left side* that is most suitable to use since it has best grades on the different criteria. The plan type *border strip on the left side* does give an excellent character of the street, environment, subjective safety/security as well as an excellent wanted influence on modal split. The investment and maintenance is high for this type but this is not used as a decision factor in this evaluation. The alternative *no change of the plan* would have an unacceptable influence on modal split for the wanted Bicycle Priority Street and is therefore not an option. An increased share of bicycles is essential. Looking at the character of the street, the plan type *border strip on the left side* and *wide border strip on the left side* explains better than the plan type *border*

strip on the right side how to use the street since the border strip will not be mistaken for a bicycle lane on the left side. The plan type *wide border strip on the left side* gives a higher environmental effect than *border strip on the left side*. This is due to that motorized vehicles always have two wheels on the border strip contributing to an increased noise level and it does also give a much smaller bicycle infrastructure.

For the other two Bicycle Priority Street-types, one-way Bicycle Priority Street for motorized traffic and two-way for bicycles and two-way Bicycle Priority Street for both motorized traffic and bicycles, the most suitable plan types according to the Table 13 and 14 is the ones with border strips. The plan types *no change of the plan* have unacceptable effects on influence on modal split of the wanted Bicycle Priority Street on these types of streets. The difference between the plan type *border strip* and *median* is that the border strip gives a wider bicycle infrastructure which is preferable on the Bicycle Priority Street because of the bicyclist's priority.

It can be seen in all three Tables 12-14 that the alternative of having a normal mixed traffic street like today is just as good as implementing a Bicycle Priority Street with no change of the plan. It is just the maintenance cost on the Bicycle Priority Street with no change to the plan that is higher than on a normal mixed traffic street since the Bicycle Priority Street should have good maintenance for the bicyclists comfort and safety.

5.5 Surface

Since the Bicycle Priority Street is constructed to increases the availability for the bicyclists, the surface on the Bicycle Priority Street should be as comfortable as possible for this road user. It is therefore recommended to use asphalt on the lanes that the bicyclists use. Asphalt is considered to be the most comfortable surface for bicyclists and it is, with proper maintenance, even which minimizes the risk of single accidents. To ensure that the bicyclists and the motorized vehicle understand where they should be located on the Bicycle Priority Street it is recommended to use different kind of surfaces.

The border strip is recommended to not only be visual, with for example paint on the ground, because it does not give a sufficient speed reducing effect. The border strip is recommended to be in a material not being comfortable for the bicyclists but that the motorized vehicle can drive on. This contributes to guide the road users into using the Bicycle Priority Street correctly. It is recommended to use cobblestone or concrete tiles. The concrete tiles give a smoother surface and can therefore be mistaken as a bicycle path more than the cobblestone which would remove the function of the Bicycle Priority Street. On the other hand, cobblestones is a more uneven surface which is a larger traffic safety problem than the concrete tiles if the bicyclists happen to be located on it even though they should not. It is recommended to analyze the situation on every Bicycle Priority Street that is built to conclude which material should be used on the specific street. It is also essential to have good maintenance on the Bicycle Priority Street since pot holes and rain puddles is a traffic safety risk. The pot holes must be fixed before they become a traffic safety problem.

5.6 Parking

One of the aims and functions of a Bicycle Priority Street is to fill out missing links in the bicycle network where there is no space for implementing bicycle paths. On many streets in residential areas, there would however be available space if the parking lots were to be removed. This would though in many cases demand another solution for

parking, something causing political and economic problems. Therefore it is essential to create a Bicycle Priority Street that also is possible to implement on streets with parked cars on the side, even though it is advisable in a traffic safety point of view to not allow parking on the street. Parked cars demand attention from both the driver, is an obstacle for the bicyclists and opening car doors is a big issue regarding safety for the bicyclists. One way of decreasing this type of accident is to implement safety strips between the parked vehicle and the driving lane, so that if a door is opened without paying attention to the street, it does not lead to a probability of an accident.

Hence, if parking is to be built on the Bicycle Priority Street it should be parallel to the driving direction with a safety strip on the side. This is to ensure that the parked cars are located far enough to be able to open doors without disturbing the bicyclists. The recommendation is that the strip should have a minimum width of 0,75 meters, if wider it is important to make sure the safety strip will not be mistaken for a bicycle lane. This gives about the same safety area as a wide parking lot in Sweden, since the area is 2,75 meters wide, and if the parked vehicle is parked 0,1 meter from the sidewalk and is 1,8 meters wide, then 0,8 meters is supposed to work as a safety strip. But the downside with having a wide parking lot instead of a safety strip is that the vehicle can stand for instance 0,6 meters from the pavement, giving only 0,35 meters as a safety distance to the bicycle. For this reason a safety strip is recommended instead of a wide parking lot. The safety strip is recommended to be in the same material as the border strip since they fill the similar functions. It also works as a visual narrower when no parked cars are present.

To make sure that the parking lots on the sides do not make the street look wider than it is and give high speeds on the moving motorized vehicles the parking should be interrupted as demonstrated in Figure 21 below. The interrupters could have some esthetically positive furniture such as trees and benches and in that way contribute to a more vivid urban space. It is in this case important that the left side of the safety strip, in the direction of the vehicles, is in line with the outer side of the interrupter. If right side would be in line with the interrupter it would make the Bicycle Priority Street wider and the speeds of the motorized vehicles larger than desired.

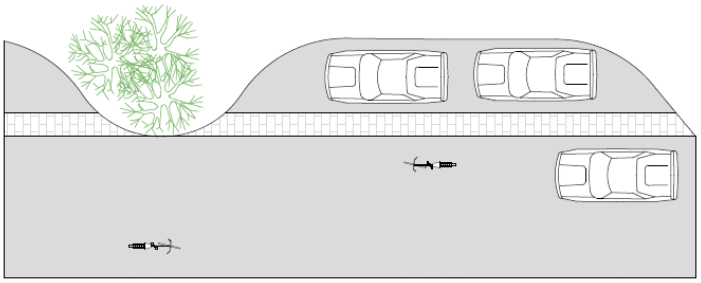


Figure 21 Refuges between parking lots making the street narrow.

Parking parallel to the direction of the moving traffic is the recommended parking solution on the Bicycle Priority Street. On the one-way Bicycle Priority Street for both bicycle and motorized vehicle it is however recommended to have diagonal reverse parking. This type of parking ensures the traffic safety on the Bicycle Priority Street since the driver can see the bicyclists easier. On the other types of Bicycle Priority Streets this is an unacceptable option since that type of parking then increases the risk of accidents on the street. On the plan types where there is a border strip on the sides the strip has the function of being a safety strip as well.

5.7 Intersection

A Bicycle Priority Street strives to give the bicyclists strengthened position in the infrastructure. In order to contribute to this it is essential to prioritize the bicyclists in the intersections of the Bicycle Priority Street. This would make the bicyclists the dimensioned traffic mode on a street created for them. Even though this priority is not optimal in a traffic safety point of view, it is an essential component for creating an infrastructure aimed to the bicyclists. Hence, an intersection that is both safe and give priority to the bicycles is necessary.

It is better, from a traffic safety point of view, to integrate the bicycles with the motorized vehicles in intersections than having separate bicycle paths. This is due to the reduced danger for the bicycles when motorized vehicles turn right. This might not be a big problem in the intersections with Bicycle Priority Streets since the majority of the bicycles continue on the Bicycle Priority Street after the crossing. However, some cars will turn right and enter or exit the Bicycle Priority Street and it is important to design this entry in a safe way. Especially if it is a rare situation that motorized vehicles enter and exit the Bicycle Priority Street, then the bicycles might not be prepared for the situation.

When different road users use the same space it is essential to have maximum speed of 30 km/h, and additional physical measures are needed to make sure that 85 percent of the motorized vehicles do not exceed this limit. This speed is needed on both the intersecting road and the Bicycle Priority Street on the crosswalk to ensure a safe passage for the bicycles. On the Bicycle Priority Street, the motorized vehicles and the bicycles are sharing the same space, making it essential to also ensure a low speed on the entire road, not only in intersections. For the intersecting road the speed needs to be reduced especially in the specific intersection, which can be done implementing different traffic calming measures before the intersection or raise the level of the crosswalk. These, among other solutions for a safe intersection are evaluated in Table 15. The aim is to have a safe passing for the bicyclists and at the same time provide an increased priority for the bicyclists, why these are the factors evaluated.

From Table 15 on next page it can be concluded that what design of the intersection to use depends on the conditions on the location. On the Bicycle Priority Street the bicyclists is the prioritized traffic mode and it is important to demonstrate this, but at the same ensure a safe passing for the bicycles. To guarantee a slow speed is essential. Some solutions mentioned in the table demand much space which might not be suitable on a Bicycle Priority Street since this type of street is mostly implemented on roads in dense areas.

Table 15 Evaluation of the different types of intersections/crossings.

Raised crossing	+	Decreases the speed of the motorized vehicles
	-	Bicyclists pay less attention and get less observant and careful
	The bicyclists get an increased possibility of being prioritized but this improved freedom to pass might lead to a too increased risk taking	
Speed reducing facility before crossing	+	Decreases the speed of the motorized vehicles
		Makes the bicyclists observant and lowers the speed
	-	Possibility to accelerate and have higher speed at the crossing
		The daily bicyclists know that the speed of the motorized vehicles are low and therefore get less observant
	The reduced speed leads to an increased possibility of giving the bicyclists priority	
Narrow crossing	+	Decreases the speed of the motorized vehicles
		Reduced time needed for the bicyclists to pass the intersection
	-	The motorized vehicles might focus on meeting each other
		Not as efficient as a traffic calming measure as speed bumps or raised crossings
	This option increases the possibility of an improved priority for the bicycles, but compared to the previous two it has the least effect	
Traffic island	+	Solution when the traffic flow is big on the intersecting road
	-	Can be an obstacle for the bicyclists
	This measure is for situations when it is difficult to cross the whole road in one step, meaning it is not a solution for increasing the priority for the bicyclists since they do not want to stop on the middle of the road	
Colored crossing	+	Increases the attention of the motorized vehicles
	-	Bicyclists get less observant and careful
	It increases the priority of the bicycles since it demonstrates that it is their space	
Signals	+	Good traffic safety solution when high flows of motorized vehicles
	If implementing green wave or other detectors the bicyclists get a more obvious and notable space, but otherwise the bicyclists are not prioritized	
Roundabout	+	Good traffic safety solution when high flows of motorized vehicles
	With this measure all the road users drive under the same conditions. It is however not a dense solution	
Flyover	+	If used correctly it is a good traffic safety solution when high flows of motorized vehicles
	As the previous measure all the road users drive under the same conditions and it is not a dense solution	

5.8 Speed Reducing Facilities

To ensure good traffic safety and subjective safety/security on the Bicycle Priority Street it is important that low speed levels are reality on the street. The Bicycle Priority Street should itself be a measure that both lowers the speed and makes sure the road users do not exceed it. Hence, the traffic sign with the speed limit should be combined with other speed reducing facilities to ensure low speed levels on the Bicycle Priority Street. Different speed reducing facilities do exist and it is recommended that on every Bicycle Priority Street that is made it is analysed which facility that is best suited on that street looking at the amount of bicycle traffic there will be and what kind of motorized vehicle that will use the street. The facilities have different speed reducing effects, essential to consider since this correlates with the accident rate and therefore traffic safety. It also has to be taken into account the frequency of the measures, since they only reduce the speed on the spot and not the whole street. When reducing the speed and the availability for the motorized vehicles it has to be taken into account that the surveillance vehicles must be able to access the road. Speed bumps are not beneficial but at the same time they work as prevention for accidents.

The speed reducing facilities possible to implement on a Bicycle Priority Street are being discussed below. To be noticed is that not much research has been found about traffic calming measures for bicycles and what impact they have on both traffic safety and availability, something that has to be further investigated.

A narrow street leads to less space to manoeuvre on during unpredictable situation, but if using a border strip in the plan, this strip can also be used as a safety strip. When having narrow sections on the street, a bypass is one solution in order to increase the availability and at the same time reduce the speed of the motorized vehicles. Also when implementing bumps on the street, bypasses can be used. Bypasses have to be conducted without making the edges of the bypass an obstacle for the bicyclists. Bumps have the largest traffic calming effect but they cause noise and vibration and are probably the most uncomfortable solution for the bicycles.

Shifting the street also reduces the speed, but as it demands more space it might therefore not be a suitable solution for a Bicycle Priority Street. It also forces the bicycles to take small detours which lower the availability. Noise strips decrease the comfort for the bicycles but is a good solution when aiming to lower the speed for both the bicycles and motorized vehicles, for instance just before an intersection.

Speed cameras are not uncomfortable and do not reduce the availability of the bicycles. The drawdown is that they are not common in the urban environment and might contribute to an unwanted urban space with a feeling of being controlled by the government.

5.9 Sign and Pictogram

It is recommended to use both sign and pictogram on the Bicycle Priority Street in order to make it easier for all road users to know what kind of street it is and how to behave. It is suggested to use only one type of sign on all Bicycle Priority Streets in order to not confuse the road users, and the sign should show in pictures what the aimed traffic usage is. This is to ensure the road users not familiar to the street know how to act, what obligations they have and that the motorists are guests on the street. The pictogram should, preferably, have the same picture as the sign to show continuity and not confuse the road users which could be a traffic safety problem.

The sign should also be addressed to both the motorists and the bicyclists and therefore both should be shown on the sign to ensure they understand they are permitted to use the street. The sign and pictograms should be located at the entrance of the Bicycle Priority Street to show what kind of street the road users are entering. The pictogram is recommended to be repeated on long Bicycle Priority Streets to clarify that the road users are aware of their obligations on the street all the way to the exit, where there should be a sign telling the road users they are exiting a Bicycle Priority Street.

6 Theoretical Try-out in Majorna

Three streets in the urban district Majorna in Gothenburg have been chosen for making a theoretical try-out, one for each Bicycle Priority Street type evaluated in Chapter 5.4. The neighborhood Majorna is the investigated neighborhood since this is where the accidents in STRADA were evaluated. Each street is explained in an own chapter, followed by the evaluation of the traffic safety and secondly by the evaluation of the qualities *street character, modal split, environmental effects* and *subjective safety/security*.

The streets were chosen by:

- Evaluate if the Bicycle Priority Street at that location would fulfill its function. The most important functions are considered to be;
    - missing link
    - solution for dense area
    - increased availability for bicyclists
- Using GIS as a tool with data about accidents in the area from the analysis in Chapter 3.2.2
- Bicycling on the street to get a feeling of the street and evaluate the possibilities to implement a Bicycle Priority Street

All places are unique. Two road sections with the same or similar design have different presumptions in terms of different flows, modal split, even if those differences can be rather small. However, an accident occurring in one place can sometimes be assumed to have the same probability of happening at a similar place, the reason of the location of a specific accident is sometimes more a coincidence. For instance could a single accident where a bicyclist drove into a pole due to lack of attention have happened 20 meters earlier where another pole is situated. The presumptions influence the probability of an accident, but often those presumptions are similar on several locations and make the accident a non-specific accident.

For this reason it is important to investigate the cause of an accident, and not only make sure to implement measures against the specific reason of the accident. Not only should the mentioned pole in the earlier example be removed, but all similar poles. This leads to the conclusion that even though an accident has not occurred on a street the last twelve years this does not mean that there is no probability of an accident to occur. Since the streets in Majorna have quite a similar design and character many of the accidents happened on another street than the ones chosen as the try-out streets are assumed to be able to happen on these as well. One of these accidents is for instance opening of car doors, which has caused several accidents in Majorna.

To compare the traffic safety impact on the three speed alternatives *30 km/h*, *20 km/h* and *bicycle speed*, the speed level on the future Bicycle Priority Street has been set as the speed limit. It is assumed, and also a requirement, to assure that the mean speed level does not exceed the speed limit. The 85-percentil on the different alternatives has the same proportion as the speed today, meaning that the speed distribution curve is only moved and not modified. To get the mean speed on the streets today, speed measurements have been made on the street and can be found in Appendix IV, VI and VII. More measurement would strengthen the result and the pedestrians are not included in the analysis.

To evaluate the other qualities; *streets character*, *modal split*, *environmental effects* and *subjective safety/security* value roses are made to compare the option of doing nothing to a mixed traffic street to the option of implementing a Bicycle Priority Street on the street. Different criteria have been set to the qualities, and depending on how the criteria are satisfied the value rose is graded, see Appendix V for the grading.

6.1 Ekedalsgatan

The chosen try-out street for implementing a Bicycle Priority Street with one-way Bicycle Priority Street for both motorized vehicles and bicycles is the part of Ekedalsgatan marked in Figure 22 below.

Figure 22 The black rectangular shows the part of Ekedalsgatan that is suggested to be a Bicycle Priority Street. The red color shows the bicycle network, the red lines shows the bicycle paths and the red dotted lines shows where the bicycle are mixed with motorized traffic (Göteborg Stad, 2012).

The chosen part of the street is separated with a tram track between the streets, see Figure 23. This forms one road in each direction with one-way traffic. This part is a drive-through street with tenement buildings and some businesses on the ground floors as well as a tram station in the middle of the street. It has a high amount of motorized vehicles on the street, 2650 motorized vehicles/day per direction (Göteborg Stad, n.d b). The share of bicycles is about half the amount of the motorized vehicles, see Appendix V.

Figure 23 Traffic situations at Ekedalsgatan, Majorna (Photo: Helena Denvall).

There are parking lots parallel to the street located on the street. The speed limit on the street is 50 km/h and the speed level is 36 km/h. Both roads are narrow, when

bicycling on the street it is so narrow that a motorized vehicle is not always able to overtake a bicyclist, as can be seen in Figure 23 on the previous page. Hence, it is a stressful and unsafe urban space and the bicyclists are often forced to the empty parking lots in order to give way to the motorized traffic. Some speed reducing measures have been implemented on the street, there is a road pillow bump when entering this chosen section of the street and there are also some narrowing sections on the street. The street has a low share of truck traffic.

This part of the street forms a missing link in the bicycle network between bicycle paths. Today the bicyclists have to share the road with motorized traffic on the motorist's conditions. Therefore an implementation of a Bicycle Priority Street could delete this missing link and increase the availability and attractiveness for the bicyclists. An implementation of a Bicycle Priority Street also fills the function of a solution for a dense area since the roads are narrow and there is not much space for implementing bicycle paths unless removing the parking lots. It would also fill the function of being traffic calming.

An implementation of a Bicycle Priority Street with the plan type *border strip on the left side* has to ensure that the speed level not exceeds the speed limit. This can be obtained with a narrowing of the plan with for example making safety strips that also works as border strips next to the parking lots. Also more speed reducing facilities needs to be implemented.

Since the share of motorized vehicles is of such a large extent compared to the bicycles some measures, beyond implementing Bicycle Priority Street, to decrease/move motorized vehicles needs to take place. How this impacts the surrounding streets and infrastructure is not investigated.

This part of the street does not have any intersections with other roads except for the locations when entering and exiting the street which have to be made traffic safe. The north enter/exit of the street is a roundabout where the entering and exiting to the remaining bicycle paths is made traffic safe. At the south enter/exit to the bicycle paths there is a big intersection that needs to be design traffic safe and that prioritizes the bicyclists. Today the intersecting road users are obliged to give way to Ekedalsgatan.

6.1.1 Evaluation of the Speed

The mean speed measured on Ekedalsgatan was 35,66 km/h as can be seen in Table 16 below. The 85-percentil was 39. The measurements were taken about ten meters before a speed bump and the mean maximum speed on the street is therefore assumed to be slightly higher in reality. Table 16 below shows the different speeds.

Table 16 Mean speed, 85-percentil and 15-percentil of the current situation and the three different speed alternatives.

	Today	30km/h	20km/h	Bicycle speed
Mean speed	35,66	30,00	20,00	16,00
85-percentil	39,00	32,81	21,87	17,50
15-percentil	30,65	25,79	17,19	13,75

The three speed alternatives are used in the power model in order to calculate how the probability of a severe or fatal accident has been changed after the try-out compared with today´s situation. Figure 24 on next page shows the result, to follow the calculation see Appendix IV.

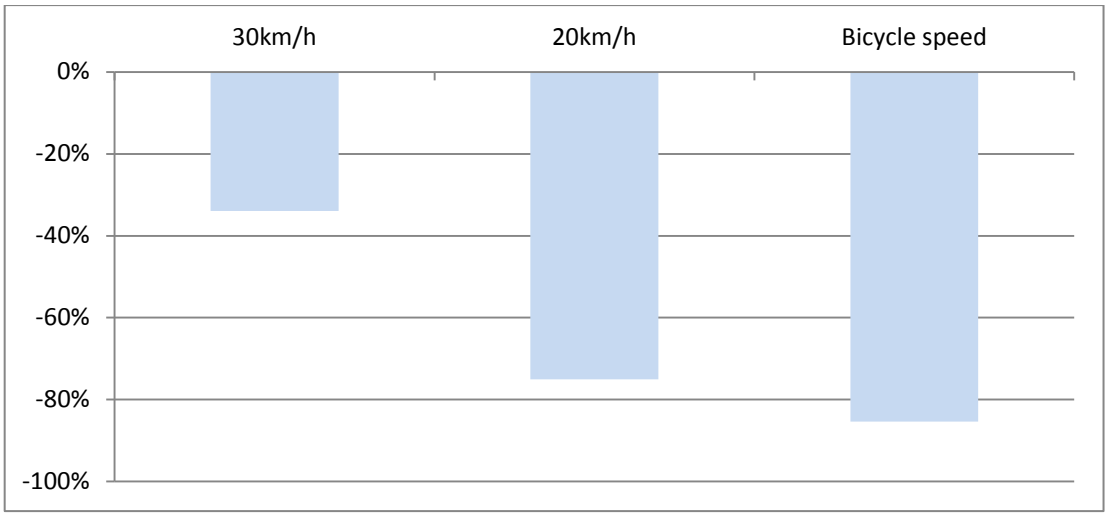


Figure 24 The change of the probability of severe and fatal accidents when implementing the new speed limits on Ekedalsgatan according to the power model

All three speed alternatives improve the traffic safety and 20 km/h and bicycle speed are the options with the largest effect. The aim of Vision Zero is to improve the traffic safety with 50 percent and both these alternatives contribute to a decreased probability of a severe and fatal accident with 75 to 85 percent.

6.1.2 Evaluation of the Infrastructure

The impact on the different qualities in infrastructure, *Character of the street, Modal split, Environment* and *Subjective safety/security* is shown in Figure 25 below.

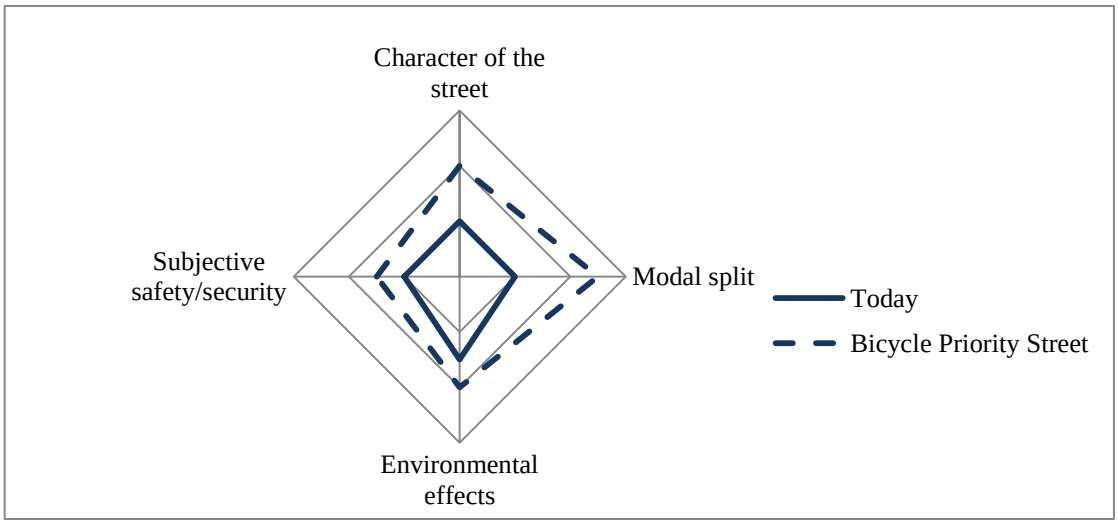


Figure 25 Value rose for changes in qualities on Ekedalsgatan when implementing a Bicycle Priority Street compared to today.

An implementation of a Bicycle Priority Street lowers the speed of the motorized vehicles which improves the character of the street as well as the environmental effects. Also the desired effect of more bicycles and less motorized vehicle is to be achieved with an implementation since the reduced speed also raises the subjective safety/security. But still, the bicycles share the area with the motorised vehicles which contributes to some unsecure feelings.

6.2 Allmänna Vägen – North East

The chosen try-out street for implementing a Bicycle Priority Street with one-way traffic for the motorized traffic and two-way traffic for the bicycles is a part of Allmänna vägen that can be seen in Figure 26 below.

Figure 26 The black rectangular shows the part of Allmänna vägen that is suggested to be a Bicycle Priority Street. The red shows the bicycle network, the red lines shows the bicycle paths and the red dotted lines shows where the bicycle are mixed with motorized traffic (Göteborg Stad, 2012).

This part of Allmänna vägen has one-way traffic for the motorized vehicles but two-way traffic for the bicycles. The street is surrounded by old tenement buildings and there are some businesses on the ground floors. There is also a big grocery store at the eastern side of this part of the street that gives some, for a Bicycle Priority Street, unwanted drive-through-traffic on this part of the street. But the one-way direction for the motorized vehicles keeps the amount of this traffic low.

Figure 27 The north east part of Allmänna vägen (Photo: Helena Denvall)

There are many bicyclists using the street, and the bicycle traffic is lead from parallel roads towards Allmänna vägen. The amount of bicycles is about four times the amount of motorized vehicles during peak hours, see Appendix VI.

This part of the street has the speed limit 50 km/h but on the western part of this section of the street it is recommended to drive in 30 km/h. The north east part of Allmänna vägen has cobblestoned surface which makes the motorized vehicles reduce their speed, see Figure 27 on the previous page. The surface is also shifting in the middle which is speed reducing. The mean speed level on the street is 17 km/h, see Appendix VI. The street is narrow and the plan is too narrow for implementing a bicycle path, but there is sufficient space for the motorized vehicle to overtake bicyclists. There is parking parallel to the driving direction located on the street, and the amount of trucks is low.

The street is a missing link in the bicycle network as can be seen on the map in the Figure 26 on the previous page, since the bicyclists have to share the road with motorized traffic on the motorist's conditions. Hence, an implementation of a Bicycle Priority Street could delete this missing link and increase the availability for the bicyclists. An implementation of a Bicycle Priority Street also fills the function of a solution for a dense area since the road is narrow and there is not enough space to implement bicycle paths.

When implementing a Bicycle Priority Street on the this part of Allmänna vägen, the cobblestone is removed in order to have the desired plan design of asphalt in the middle and border strips on the sides. Since there is a lot of parking safety strips needs to be implemented which is traffic calming, but other speed reducing measures need to be implemented as well.

There is only an intersection at the west side of this street where the intersecting traffic has a speed limit of 30 km/h because of a nearby school. The intersection has speed reducing measures, the intersection is raised and there are noise strips for the crossing traffic and in addition the intersection is narrowed from all directions. There are two streets that end on this section of the street, one from the south where the right-hand rule gives the traffic on the Allmänna vägen priority and one from the north where the right hand rule oblige the traffic on Allmänna vägen to give way to the traffic from the other street. At an implementation of a Bicycle Priority Street these intersections needs to be changed so the bicyclists are prioritized instead.

6.2.1 Evaluation of the Speed

On the north east part of Allmänna vägen, the mean speed is measured to 17 km/h, way below the speed limit of 50 km/h, see Table 17, which is trustworthy since the street is short and there are few possibilities and reasons of accelerate when entering the road. The cobblestone might also be a contribution to the low speed.

When implementing a Bicycle Priority Street on this road, and for instance lower the speed from 50 km/h to 30 km/h the speed is not believed to increase. The road has a large share of bicycles today, which might be a contribution to the low speed, and this number will probably rice. The only factor that might increase the speed is that the cobblestone is replaced by asphalt. However, the additional design must assure that the speed is kept as today or is lowered. It is not acceptable to have the speed increased after the implementation since then a large reason of the Bicycle Priority Street is lost. With this argument, the mean speed levels at the speed levels of 30 km/h and 20 km/h are chosen to be as today.

Table 17 Mean speed, 85-percentil and 15-percentil of the current situation and the three different speed alternatives.

	Today	30km/h	20km/h	Bicycle speed
Mean speed	**17,06**	17,06	17,06	16,00
85-percentil	**22,00**	22,00	22,00	20,63
15-percentil	**12,00**	12,00	12,00	11,25

Since the speed levels at 30 km/h and 20 km/h are set to remain as today, these new speed limits do not have an effect of the traffic safety, see Figure 28 below. The speed option *bicycle speed* only decreases the probability of a severe and fatal accident with 15 percent.

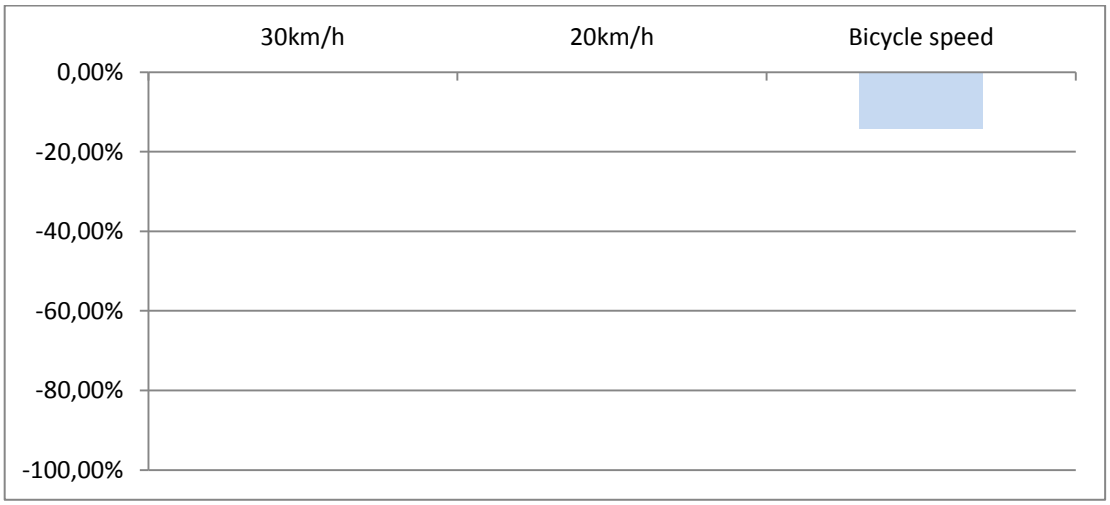


Figure 28 The change of the probability of a severe and fatal accident when implementing the new speed limits according to the power model on the north east part of Allmänna vägen.

6.2.2 Evaluation of the Infrastructure

The value rose for the Bicycle Priority Street on the north east part of Allmänna vägen can be seen in Figure 29 below.

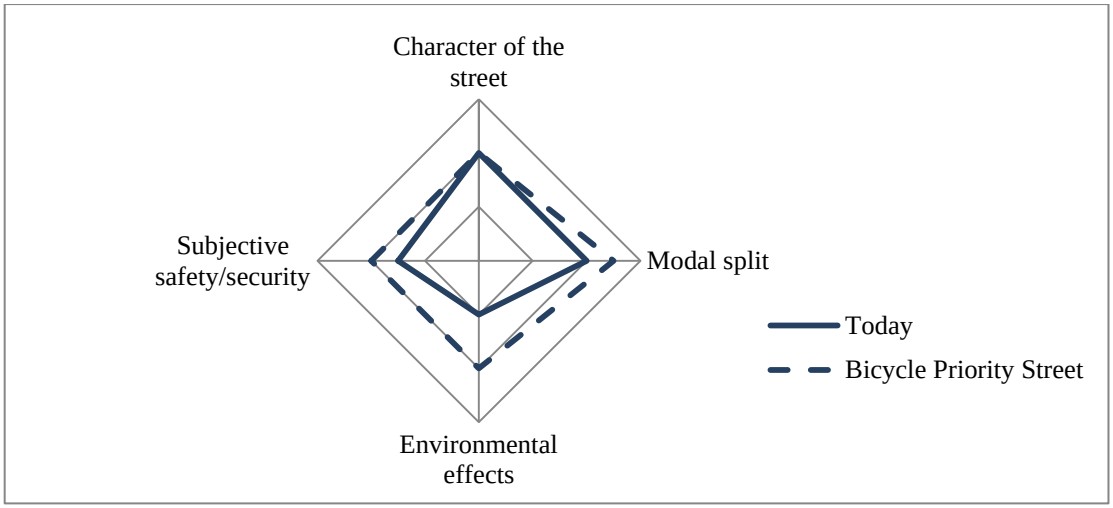


Figure 29 Value rose for changes in qualities on the north east part of Allmänna vägen when implementing a Bicycle Priority Street compared to today.

The character on this part of Allmänna vägen is considered vivid and sociable with its old buildings and cobblestoned surface. An implementation of a Bicycle Priority Street would remove some of the cobblestone and change the character but this would

be compensated by the reduced motorized traffic. Both the absent of motorized vehicles and cobblestone will improve the environmental effects. The share of bicycles is quite high today but a Bicycle Priority Street would increase it even more and also the amount of motorized vehicles would be reduced which will improves the subjective safety/security. Some motorized vehicles will however remain and contribute to a lower subjective safety/security for the bicyclists.

6.3 Allmänna Vägen – South West

The chosen try-out street for implementing a Bicycle Priority Street with two-way Bicycle Priority Street for both motorized vehicles and bicycles is the south west part of Allmänna vägen as can be seen in Figure 30 below.

Figure 30 The black rectangular shows the part of Allmänna vägen that is suggested to be a Bicycle Priority Street. The red shows the bicycle network, the red lines shows the bicycle paths and the red dotted lines shows where the bicycle are mixed with motorized traffic (Göteborg Stad, 2012). The Orange line is a modification made by the authors of this thesis since the map was not updated to show that there is a bicycle path.

Today this part of Allmänna vägen has two-way traffic for both motorized vehicles and bicycles. The street is surrounded by old tenement buildings and the motorized traffic is considered to be mostly local. There are many bicyclists using the street, and the bicycle traffic is lead from parallel roads towards Allmänna vägen.

Figure 31 The south west part of Allmänna vägen (Photo: Helena Denvall).

This part of Allmänna vägen forms a missing link in the bicycle network, as can be seen in the Figure 31 above, since the bicyclists have to share the road with motorized traffic on the motorist's conditions. Therefore an implementation of a Bicycle Priority Street deletes this missing link and increases the availability for the bicyclists. There is not much space on the street; hence an implementation of a Bicycle Priority Street would fill the function of a solution for a dense area.

When implementing a Bicycle Priority Street the plan type with border strips is recommended, and it is important that the speed level does not exceed the speed limit. Parking lots need to be surrounded by safety strips which also give a visual narrowing of the street and is speed reducing.

There is one intersection located between the two sections of the street where the intersecting traffic has the speed limit of 50 km/h with both the speed reducing facility of a bump before entering the intersection and narrowing refuges for the crossing traffic. At the north enter/exit of the street there is an intersection where there is a speed reducing facility for the bicycle traffic coming from the bicycle path on Allmänna vägen, and none for the motorized traffic. These intersections need to be changed in order to prioritize the bicyclists.

6.3.1 Evaluation of the Speed

The mean speed measured at the south west part of Allmänna vägen is 19 km/h. Since the speed measure instruments were visible during the measuring it might have impacted the result and the maximum mean speed on the street is considered to be slightly higher than presented in Table 18.

The speed limit is 50 km/h and the mean speed is remarkable lower. The same reasoning is done here as for the north east part of Allmänna vägen, assuming the speed not to be increased and therefore the speed level at the options 30 km/h and 20 km/h are set to be the same as today.

Table 18 Mean speed, 85-percentil and 15-percentil of the current situation and the three different speed alternatives

	Today	**30km/h**	**20km/h**	**Bicycle speed**
Mean speed	**19,15**	19,15	19,15	16,00
85-percentil	**23,75**	23,75	23,75	19,85
15-percentil	**15,00**	15,00	15,00	12,53

Not changing the speed levels at the alternatives 30 km/h and 20 km/h does not have any impact on the traffic safety when calculating with the power model, see Figure 32 on the next page. Bicycle speed does however reduce the probability of a severe and fatal accident with 35 percent.

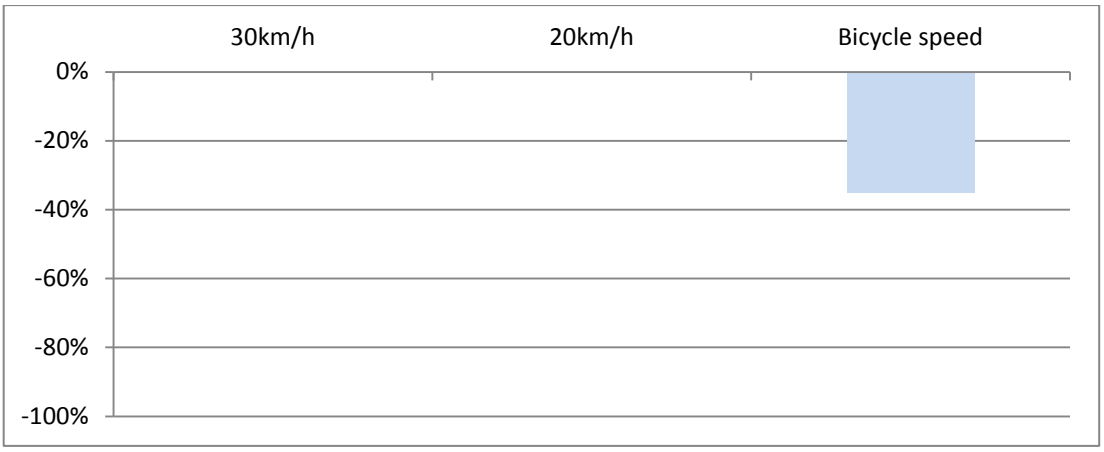


Figure 32 The change of the probability of a severe and fatal accident when implementing the new speed limits according to the power model on the south west part of Allmänna vägen.

6.3.2 Evaluation of the Infrastructure

The value rose for a Bicycle Priority Street on the south west part of Allmänna vägen can be seen in Figure 33 below.

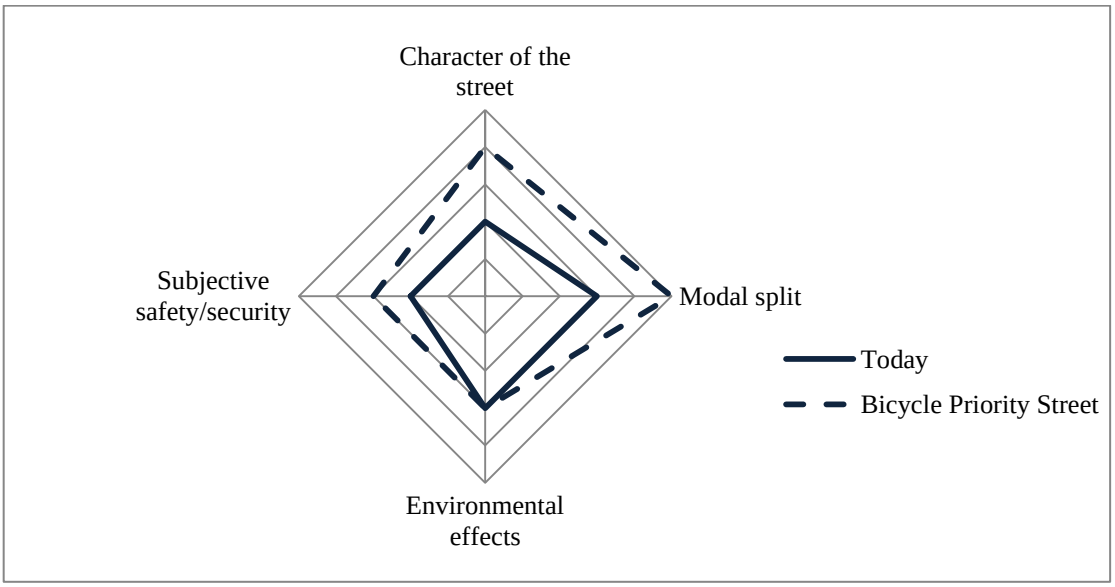


Figure 33 Value rose for changes in qualities on the south west part of Allmänna vägen when implementing a Bicycle Priority Street compared to today.

The character of the street is improved when implementing a Bicycle Priority Street on this part of Allmänna vägen. This is due to the reduced amount of motorized vehicles which also leads to better environmental effects on the street. The uneven surface does however contribute to an increased level of noise and vibrations. The subjective safety/security is improved when implementing a Bicycle Priority Street but sharing space with the motorized vehicles would still cause some unsafe feelings.

7 Traffic Safety Evaluation

The main reason for implementing a Bicycle Priority Street is to use it as a solution of fulfilling a complete bicycle network when there is no space for having a bicycle path. Hence, a Bicycle Priority Street can be constructed even though there were no accidents on the road earlier. Then the Bicycle Priority Street has to either improve the traffic safety or, if the traffic safety already was considered satisfying, make sure the level of the traffic safety stays the same. How the traffic safety is changed when implementing the Bicycle Priority Street depends on the conditions of the road before the Bicycle Priority Street was implemented. But even though an accident has not occurred the last years does not mean it will not happen in the future.

As could be seen in Chapter 6 the speed at the Bicycle Priority Street is either reduced or remained as today, and shall not increase the speed level of the motorized vehicles. How much the speed is reduced depend on the current speed level as well as which speed limit is chosen to be implemented on the Bicycle Priority Street. It is concluded that a reduced speed contributes to an improved traffic safety, on one of the try-out streets the probability of a severe or fatal accident was reduced by 85 percent when having bicycle speed. On the two other try-out streets the traffic safety was however constant when implementing 30 km/h or 20 km/h. To obtain these results it is important to ensure the speed limit is not exceeded by implementing speed reducing facilities.

Many studies have been conducted to evaluate the effect on speed reducing measures to give a range of how much they reduce the accident rate. These numbers are used in this report, but are not considered absolute but indicators of an improved traffic safety.

However, there are several measures and factors implemented when constructing the Bicycle Priority Street that have verified effects on traffic safety. These factors are evaluated to see if the traffic safety for the bicyclist is improved when implementing a Bicycle Priority Street instead of having mixed traffic, see Table 19 below.

Table 19 Verified traffic safety effects on different elements.

Element	+	-
New rules and signs	Lowers the speed limit with 10 km/h → 3-4 km/h reduction of speed level 20 km/h → 6-8 km/h reduction of speed level	
Pictogram	Makes the road users know what kind of street it is	
A complete bicycle network	Increases the number of bicyclists	
Safety strip	Prevents accidents with opening cars doors	
Border strip	Helps the road users to know how to act Works as a safety strip when there are parked cars, without making the street wider	Less confused road users which contributes to less observant road users
Uneven surface	Lowers the speed for motorized vehicles Increases the skid resistance	If the bicycles happen to be there it is an increased risk of single accidents.

Even		Less risk of single accidents	Increases the speed
Intersection		Positive effect to have integration A speed of 30 km/h is assured	
Priority			Can lead to high speeds Increases the amount of motorized vehicles The bicyclists get less observant
Parking			Work as obstacles Demands attention from the road users Opening of car doors a problem
Median		Reduces the accident rates	To have it in curves increases the accident rate Curbed is preferred compared to visualized
Narrowing		Reduces the speed	Less space for unpredicted situations Reduces the subjective safety/ security Space for fescue needs to be assured
Increased amount of bicyclists		More than 50 bicyclists/hour increase the traffic safety remarkable	
Decreased amount of motorized vehicles		Fewer situations where conflicts may occur	More vehicles lead to more attention. But, the bicyclists are intended to increase which compensate this loss of attention for other cars The bicyclists do not have as much attention towards the motorized vehicles
Subjective safety/security		Makes the road users more cautious	
Integration		On streets with low traffic and no centerline the traffic safety is improved compared to lanes	
Interaction		An enabled interaction contributes to an improved traffic safety Interaction requires low speeds which improves the traffic safety	Not all road users are capable of interacting
Traffic calming measure	**Occasional narrowing with bypass for bicycles**	Reduces the speed	Can be an obstacle for bicycles. Needs special maintenance, otherwise it can cause single accidents
	Occasional narrowing with shifting the street	Reduces the speed Reduces the willingness to accelerate	Risk of reduced visibility Difficult maintenance which increases the single accidents
	Bumps	The speed reducing facility with largest effect	Not much is known about the effects of bicyclists
	Speed cameras	Reduces the speed just before the camera	

The verified traffic safety effects highlighted in the Table 19 above shows that there are both positive and negative effects when implementing a Bicycle Priority Street, but it has to be taken into consideration that the table does not show the extent of the consequences.

Priority is one of the functions with negative consequences, but it is a component in order to improve the bicycle network and start to create an infrastructure for all road users and not only for motorized vehicles. Therefore it is essential on the Bicycle Priority Street to make sure the bicyclists feel prioritized, even though it does not contribute to an improved traffic safety.

Parking is another factor with only negative effects. It is considered essential to enable parking on Bicycle Priority Streets. One of the ideas of a Bicycle Priority Street is to fill out missing links in the bicycle network where there is no space for implementing bicycle paths, and this might be at locations where parking cannot be removed.

A reduced flow of motorized vehicles and an increased flow of bicyclists improve the traffic safety significantly. Also the speed has a large impact; the speed reducing measures assure the wanted speed level. How much the traffic safety is impacted because of speed is depend of the presumptions of the location and how high the speed was before the implementation, as could be seen in the theoretical implementation in Chapter 6.

A Bicycle Priority Street gives the bicyclists an obvious place on the street compared to drive in mixed traffic. The Bicycle Priority Street is designed for the needs of the bicyclist, instead of having a good availability and satisfaction of the motorized vehicles, as it usually is on streets with mixed traffic. To create a street better adjusted for the unprotected road users increases the traffic safety and is one step closer to the goals of Vision Zero.

8 Conclusion

A Bicycle Priority Street is a bicycle street where the motorized vehicles are allowed on the permissions of the bicycles. It has several functions, the most important is that it works to distinguish missing links and fulfills the bicycle network where the urban space is too dense to implement bicycle paths, as well as it increases the availability and attractiveness for the bicyclist as it demonstrates that they are the prioritized road users.

Before considering an implementation of a Bicycle Priority Street, it is recommended to further investigate what happens with the traffic safety situation at night when the bicycle intensity is low and also at a high intensity of truck traffic. In addition how loading and unloading on the Bicycle Priority Street can be performed safely needs to be further investigated as well as how winter maintenance of the Bicycle Priority Street can be performed in order to ensure a high traffic safety. An evaluation of how pedestrians and mopeds are affected by the Bicycle Priority Street needs to be conducted as well.

The Bicycle Priority Street is suitable to implement on local streets with low flows of motorized vehicles. There should be a potential of having large flows of bicyclists using it and to both attract bicyclist from the surrounding streets and people earlier using motorized vehicles. To have more bicycles than motorized vehicles on the Bicycle Priority Street ensures that the road is used on the permissions and conditions of the bicyclist.

In order to make the Bicycle Priority Streets look similar in the whole country and make sure that everybody knows how the Bicycle Priority Street works and how to behave on the street, the Bicycle Priority Street should be implemented in the Swedish traffic regulations. The speed limit is recommended to be set as either 30 km/h, 20 km/h or bicycles speed; the speed of 30 km/h has the most potential of being accepted since it is being used today, while 20 km/h and bicycle speed have several positive affects both regarding traffic safety and improving the bicycle infrastructure, but might also be too controversial. What speed limit to have on the street also affects which kind of bicyclist that will appreciate the Bicycle Priority Street. The bicyclists that gain the most of an implementation are the commuters, social bicyclists and to some extent fitness bicyclists. Elderly and children are not suitable and will not appreciate the Bicycle Priority Street.

Three street plan designs have been developed during the process of the report, one for each of the street types one-way Bicycle Priority Street for both motorized vehicles and bicycles, one-way Bicycle Priority Street for motorized vehicles and two-way for bicycles and finally for two-way Bicycle Priority Street for both motorized vehicles and bicycles. These designs can be seen in Figure 34 on next page, and contribute to a better compliance of the speed limit and a priority of the bicyclist.

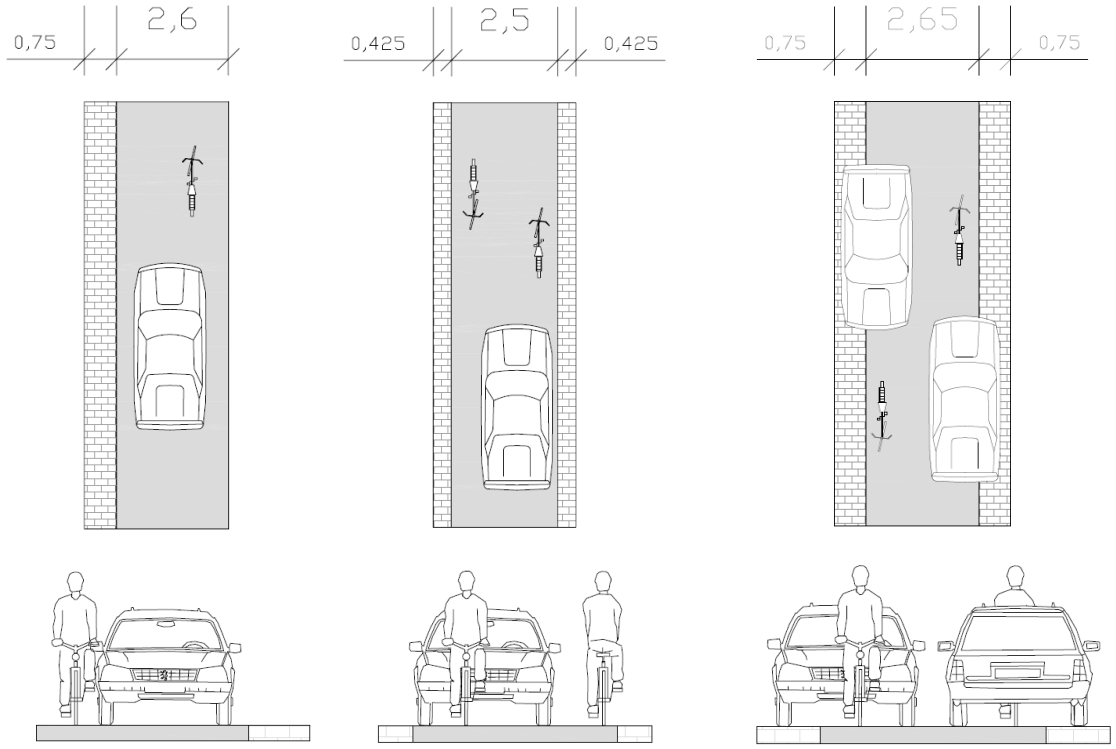


Figure 34 The recommended designs on the street plans

An implementation of a Bicycle Priority Street impacts the surrounding infrastructure, and the extent of the impact depends of the location. Three theoretically try-out streets have been evaluated in this report, and of the effects regarding character of the street, influence on modal split, environment and subjective safety/security all results were positive. The best effect was regarding the effects on modal split and character of the streets, while subjective safety/security and environmental effects mostly were just slightly improved or remained on the same level as today.

The speed of the Bicycle Priority Street will either be reduced or remained as today, and shall not increase the speed level of the motorized vehicles. How much the speed is reduced depends on the current speed level as well as which speed limit is chosen to be implemented on the Bicycle Priority Street. It is concluded that a reduced speed contributes to an improved traffic safety, on one of the try-out streets the probability of a severe or fatal accident was reduced by 85 percent when having bicycle speed. On the two other try-out streets, the traffic safety was however constant when implementing 30 km/h or 20 km/h.

Several factors impact the traffic safety when implementing a Bicycle Priority Street. Parking and priority for the bicyclists have negative effects but are essential on a Bicycle Priority Street. Some factors have both positive and negative effects, one example is border strips which contribute to an improved understanding of how to act on the street but at the same time being less confused makes the road users less observant. However, the majority of the factors contribute to an improved traffic safety. A street designed for the needs of the bicyclists in both availability and attractiveness instead of focusing on a good availability for the motorized vehicles improves traffic safety and contributes to reach the goals of Vision Zero.

9 References

ADFC (2011) *Fahrrastrassen* [Bicyle Street. In German] [pdf] Available: http://www.adfc.de/verkehr--recht/radverkehr-gestalten/radverkehrsfuehrung/adfc-position-fahrradstrassen (2013-04-08)

Belgisch Staatsblad (2012) *Art.2. <<2.61/Art. 3. << Art22novis Wetten, decreten, ordonnanties en verordeningen* [Laws, decrees, ordinances and regulations. In Dutch] [pdf] Available: http://www.wegcode.be/pdf/wijzigingen/KB011275/171212.pdf (2013-04-03)

Beumer, W (Senior Traffic Designer at the Municipality of Rotterdam) intervjued by the authors March 15 2013.

BGSV (n.d) *Castricum, Dorpstraat* [pdf] Available: http://www.bgsv.nl/pdfs/pdf-project_Castr.pdf (2013-04-15)

Boverket (2012) *PBL Kunskapsbanken* [PBL the bank of knowledge. In Swedish] [pdf] Available: http://www.boverket.se/Vagledningar/PBL-kunskapsbanken/Skapa-pdf/ (2013-02-05) 135 & 155 pp.

Boverket et al (2004) *Trafik för en attraktiv stad* [Traffic for an attractive city. In Swedish]. Malmö: Elanders Berlings AB

Bundeskanzleramt (2013) *25. StVO-Novelle – beschlossene Änderungen* [25th StVo change – agreed changes. In German] Available: https://www.help.gv.at/Portal.Node/hlpd/public/content/171/Seite.1710338.html (2013-06-01)

Böhme, B (Traffic Engineer at the Municipality of Münster) intervjued by the authors March 13 2013.

CROW (2007) *Design manual for bicycle traffic* Den Haag: DeltaHage (CROW Record 25)

Ekman, L (1996) *On the Treatment of Flow in Traffic Safety Analysis - a non-parametic approach applied on vulnerable road users* Lund: LTH, Department of traffic planning and engineering (Bulletin 136)

ELTIS (2012) *First Bicycle Street established in Ghent (Belgium)* [www] Available: http://www.eltis.org/index.php?id=13&study_id=3627 (2013-04-03)

Elvik, R et al (2009) *The handbook of road safety.* Bingley: Emerald Group Publishing Limited

Elvik R, Christensen P, Amundsen A (2004) *Summary: Speed and road accidents: an evaluation of the Power Model*. Oslo, TÖI (TÖI reprt 740/2004)

Forsbeg, I (2008) *PM - Cykelfartsgata, Hunnebergsgatan* [PM – Bicycle speed street, Hunnebergsgatan. In Swedish] VTI

Göteborg Stad (2012) *Map of the bicycle network in Gothenburg city center* (pdf) Available: http://goteborg.trafiken.nu/PageFiles/1556/Cykelkarta_Goteborg_Centrum.pdf (2013-05-23)

Göteborg Stad (n.d a) From a database in GIS

Göteborg Stad (n.d b) *Trafik* [Traffic, In Swedish] [www] Available: http://www.statistik.tkgbg.se/statistik.asp?sGata (2013-06-01)

Göteborg Stad (2009) *Historik, kunskap och analys för trafiksäkerhetsprogram 2010-2020* [History, knowledge and analysis for the traffic safety program 2010-2020. In Swedish], Göteborg Stad, Trafikkontoret (Rapport 1:2009)

Göteborgs Stad, Trafikkontoret (2000) *Farthinder som använts I Göteborgs kommun* [Speed bumps used in the municipality of Gothenburg. In Swedish] Göteborg Stad, Trafikkontoret: Rapport (6:2000)

Hahn, P-E (2013-02-26) *Cykelfartsgator* [Bicycle speed streets. In Swedish]. Personal mail contact with S. Johansson (sofiejo@student.chalmers.se) .

Hamburger, W (Dipl. Ing. In the Municipality of Bremen) (2013-01-30) *Fahrrastrasse in Bremen.* Personal mail contact with S. Johansson (sofiejo@student.chalmers.se).

Hydén, C (2013) *Om de oskyddade fick bestämma då skulle jag…* [If the vulnerable got to decide, then I would… In Swedish] Powerpoint presented at Nordiskt Trafiksäkerhetsforum – Bergen (2013-05-16)

Johansson, R & Linderholm, L (2012). *Trafiksäkerhetsprogram för attraktiva stadsrum och ett rikt stadsliv* [Traffic safety program for attractive city spaces and a rich city life. In Swedish] SKL (In press)

Lindberg, H (2009) Cykelfartsgata – försök i Linköping [Bicycle speed street – tryout in Linköping. In Swedish] [www] Available: http://www.slideshare.net/Transportforum/session-25-lisa-sakshaug?from_search=1 (2013-05-22)

Nilsson, A (2003). *Utvärdering av cykelfälts effekter på cyklisters säkerhet och cykelns konkurrenskraft mot bil* [Evaluation of the effects of bicycle lanes on bicyclist traffic safety and the ability of bicycles to compete with motorized traffic. In Swedish] Lund: LTH, Department of Technology and Society (Bulletin 217)

Nilsson, G (2000) *Hastighetsförändringar och trafiksäkerhetseffekter* [Changes in speed and effects on traffic safety. In Swedish] Linköping, VTI (VTI notat 76-2000)

Niska, A & Thulin, H (2009) *Tema cykel – skadade cyklister. Analys baserad på sjukvårdsregistrerade skadade i STRADA* [Theme bicycle – injured bicyclists. An analysis based on hospital reported injuries in STRADA. In Swedish] Linköping, VTI (VTI: rapport 644)

Rijkswaterstaat (Dutch Minitry of Transport, Public works and Water Management) (2010) *Road Traffic Signs and Regulations on the Netherlands.* Den Haag

Schenk, S (2013) *Information about bicycle streets* (Unpublished via email to sofiejo@student.chalmers.se, 2013-02-06)

SKL (Sveriges Kommuner och Landsting) (2010) *GCM-handbok – Utformning, drift och underhåll med gång, cykel- och mopedtrafik i fokus* [Handbook – Design, service and maintenance with focus on pedestrian, cycle and moped traffic. In Swedish]. Solna: Åtta45

SKL (Sveriges Kommuner och Landsting) (2009) *Åtgärdskatalogen* [Catalof of measures. In Swedish] Västerås: Edita

SKL (1998) *Lugna gatan* [The calm street. In Swedish] Stockholm: Katarina tryck

SKL & Vägverket (2008). *Rätt Fart i Staden* [The Right Speed in the City. In Swedish] Sundbyberg: Alfa Print

SOU (2012) *Ökad och säkrare cykling – en översyn av regler ur ett cyklingsperspektiv* [Increased and safer bicycling – a review of rules from bicyclists perspectiv, In Swedish] Stockholm; SOU (SOU 2012:70)

StVO (sßenverkehrs-Ordnung), Anlage 2, ifd.Nr 23, *Sonderwege* [Special streets. In German] Available: http://www.dvr.de/betriebe_bg/daten/stvo/anlage2.htm (2013-06-01)

StVO 1960, § 67 *Fahrradstrasse* [Austria] Available: http://www.jusline.at/index.php?cpid=ba688068a8c8a95352ed951ddb88783e&lawid=24&paid=67&mvpa=76# (2013-06-01)

SWOV (2010) *SWOV Fact sheet – Recognizable road design.* [pdf] Available: http://www.swov.nl/rapport/Factsheets/UK/FS_Recognizable_road_design.pdf (2013-04-11)

Tiemens, H (Traffic Expert at the Region of Utrecht) intervjued by the authors March 14 2013.

Trafikverket (2013) *Inriktning av trafiksäkerhetsarbetet, vägtrafik - vägledning inför verksamhetsplanering 2013* [Focus in the traffic safety work, road traffic – guidlines for planing of operations planning 2013. In Swedish] [pdf] Available: http://www.trafikverket.se/PageFiles/61112/inriktning_av_trafiksakerhetsarbetet_vagtrafik_vagledning_infor_verksamhetsplanering_2013.pdf (2013-01-31)

Trafikverket (2012 a) *Tillsammans för nollvisionen* [Together towards the Vision Zero. In Swedish] [pdf] Available: http://publikationswebbutik.vv.se/upload/6735/100560_tillsammans-for_nollvisionen.pdf [2013-01-31]

Trafikverket (2012b) *Analys av trafiksäkerhetsutvecklingen 2011* [Analysis of the development in traffic safety 2011. In Swedish] [pdf] Available: http://publikationswebbutik.vv.se/upload/6796/2012_098_Analys_av_trafiksakerhetsutvecklingen_2011.pdf (2013-01-31)

Trafikverket (2012c) *Slutrapport utvärdering av nya hastighetsgränser* [Final report evaluation of new speed limits. In Swedish] [pdf] Available: http://www.trafikverket.se/PageFiles/81153/slutrapport_utvardering_nya_hastighetsgranser.pdf (2013-02-11)

Trafikverket (2010) *Attraktiva stadsrum för alla - Shared Space* [Attractive urban spaces for everybody - Shared Space. In Swedish] Trafikverket (2010:122)

Trafikverket & SKL (2012a) *Krav för vägars och gators utformning* [Requirements for roads and streets design. In Swedish] Borlänge, Trafikverket (Trafikverket 2012:179)

Trafikverket & SKL (2012b) *Råd för vägars och gators utformning* [Advice for roads and streets design. In Swedish] Borlänge, Trafikverket (Trafikverket 2012:180)

Trafikverket & SKL (2012c) *Vägars och gators utformning – Begrepp och grundvärden* [Roads and streets design – Vocabulary and elementary values. In Swedish] Borlänge, Trafikverket (Trafikverket 2012:199)

Transportstyrlesen (2013) *Definitioner inom statistiken* [Definitions in the statistics. In Swedish] [www] Available: http://www.transportstyrelsen.se/sv/Press/Statistik/Vag/Olycksstatistik/Olycksstatistik-vag/Definitioner-inom-statistiken/ (2013-05-20)

Transportstyrelsen (2012) *STRADA – Användarhandledning för uttagswebb, version 3.2.0* [STRADA – User manual for the jack web. In Swedish]

Transportstyrelsen (2011) *Landstinget Västra Götaland* [County council Västra Götaland] [www] Available: http://www.transportstyrelsen.se/sv/Vag/STRADA-informationssystem-for-olyckor-skador/Rapportorer-och-anvandare/Landstinget-Vastra-Gotaland/ (2013-06-01)

Tyréns (2007) *Trafiksäkerhet vid shared space* [Traffic safety at Shared Space. In Swedish] [PDF] Available: http://www.trafikverket.se/PageFiles/3671/trafiksakerhet-vid-shared-space.pdf (2013-01-23)

Vejdirektoratet (2012) *Collection of cycle concepts* [pdf] Available: http://www.cycling-embassy.dk/2012/05/10/cycle-concepts2012/ (2013-04-19)

Vägverket (2009) *Råd för val av beläggning med hänsyn till miljö* [Advise for choice of paving with respect to the environment. In Swedish] [pdf, only digital] http://publikationswebbutik.vv.se/upload/5106/2009_124_rad_for_val_av_beläggning_med_hansyn_till_miljo.pdf Vägverket publikation 2009:124 (2013-05-23)

Vägverket (2007) *Försök med ny hastighetsgräns, 20 kilometer i timmen* [Tryout with a new speed limit, 20 kilometres per hour. In Swedish]. [Sändlista, Vägverket]. Accessed after mail contact with Isa Brisby at the municipality of Västerås (2013-01-30)

Vägverket & SKL (2004). *Vägar och gators utformning* [Roads and streets design. In Swedish] Borlänge, Vägverket (VV 2004-80)

Västerås Stad (2009) *Handlingsplan för ökat cyklande I Västerås år 2009-2013 med utblick mot 2018* [Plan of action to increase the bicycling in Västerås year 2009-2013, vista year 2018. In Swedish] [pdf] Available: http://www.vasteras.se/Tvarsnittsdokument/Teknisk%20n%C3%A4mnd/Cykelplan%202009-2013.pdf (2013-01-29)

Umeå Kommun (2000) *VGU Tätort – Övergångställe med automatisk hastighetsövervakning* [VGU Urban – pedestrian crossings with automatic speed surveillance. In Swedish] (www) Available: http://www.exempelbanken.se/examples/291 (2013-04-05)

Appendix I

Accidents involving bicyclists in Borås and Mölndal

Location of Borås and Mölndal, marked with red circles (Map from Google Maps, maps.google.com)

Borås: Neighborhoods evaluated are Byttorp/Tullen, Tandared and Hulta
Mölndal: Neigborhoods evaluated are Bifrost, Solängen, Åby and Mölndal Västra

Type of accident	Location	No. of accidents Borås	No. of accidents Möndal	
Not relevant		-	1	1
Car door	Street	-	-	-
Bicycle/car	Street	1		9
Bicycle/car	Intersection		8	
Bicycle/car	Pedestrian and bicycle path	-	-	
Bicycle/bicycle	Pedestrian and bicycle path		1	2
Bicycle/bicycle	Street	1		
Bicycle/moped		1	1	2
Bicycle/pedestrian	Street		1	2
Single accident	Unknown	1	1	7
Single accident	Street	2		
Single accident	Roundabout			
Single accident	Intersection			
Single accident	Pedestrian and bicycle path		3	
Total		6	16	

Sorted by location	Borås	Mölndal	%
Roundabout	0	0	0
Street	0	1	5
Intersection	3	9	57
Pedestrian and bicycle path	2	4	29
Unknown	1	1	10

Appendix II

			One-way BSS for both motorized vehicle and bicycle									
Criteria	Measures / Goal for the criteria		Today		Border strip on right side		Border strip on left side		Wide border strip on left side		Nothing is made to the plan	
Character of the street	Esthetics	A pleasant urban space for both traffic users and people living there; the design is considered attractive	Depends on the street, but estheticaly it is acceptable but not more	5	Depends on the material of the strip. This one not very much border strip. A strip on the right side is a common sight today making it a quite normal street.	10	Will not contribute to a radical change, but will change the character. It depends on the material on the strip.	10	The street will be divided into two, it will give it a look that you are not used to. But if the material of the stips are of estetically nice one it would be improved.	9	Will not be any improvement to the esthetics on the steet	5
	Urban density	A narrow road that contributes to a urban density	3,25 m	6	2,6-3,25 m, bike area 2,6 m	10	3,35 m, bike area 2,6 m	9	3,35 m, bike area 1,7 m	9	3,25 m	6
	An easy usage	Makes the traffic users know that the traffic should be on the bicyclists conditions and that they are the prioritezed traffic user.	-		Not very clear since the bicycles might think they should use the strip when beeing overtaken	6	Easy to understand. The bicyclist will probably not misstake a border strip on the left to be their lane. But at an overtake the bicyclists might feel forced to bicycle close to the pavement.	8	Might be confusing for a car unknown with the situation since the car will not fit on either strip, but as the car knows it is allowed on the street it is not considered a problem. At an overtake the bicyclists might feel forced to bicycle close to the pavement.	9	No	5
				55%		87%		90%		90%		53%
Environment	Noise/vibrations	No contribution to noise nor vibrations in the surroundings	The amount of motorized vehicles will stay the same and therefore there will be no improvement.	5	Not much noise nor vibrations since the motorized vehicles will drive on asphalt	10	Only noise and vibrations when overtaking bicycles	9	The motorized vehicles will drive on the more uncomfortable surface at all times, making the noise level high. If cobbled streets the vibration and noise might get unacceptable levels	4	The street will not change in design and therefore will not many traffic users change their behaviour or chose another route. So the contribution to minimize noise will be minimal. And the speed will only be reduced minimaly	5
	Emissions	No emissions on the specific road	Will stay the same	5	Positive	10	Positive	10	Positive	10	The constribution to no emissions on the road will be minimal. The speed might be a little bit lower than today	5
				50%		100%		95%		70%		50%
Subjective safety	Subjected safety bicycles	Bicyclists feel safe when using the BSS	The bicyclist feels quite unsafe and uncomfortable in mixed traffic.	3	Might feel forced to the side. Will not be disturbed by parked cars.	9	Might feel forced to the side and drive close to the pavement	8	Might feel forced to the side and drive close to the pavement	8	The subjective safety will be no larger than on a normal local street with mixed traffic today. It will feel like the motorized vehciles own the street and that they are a traffic safety threath to the bicyclists. The sign of the speed might lead to some lower speed on the mot vehicle and will make the bicyclists feel a little bit safer than today.	4
	Pedestrians	Pedestrians not directly effected in a negative way	Ok, since there are sidewalks aimed for the pedestrians	10	Ok, since there are sidewalks aimed for the pedestrians	10	Ok, since there are sidewalks aimed for the pedestrians	10	Ok, since there are sidewalks aimed for the pedestrians	10	Ok, since there are sidewalks aimed for the pedestrians	10
				65%		95%		90%		90%		70%
Traffic safety	Keeping the speed	The design of the road contributes to that the speed limit is not exceeded	With no speed reducing measures the speed is not be keept on the street	5	The motorized vehicles does allways drive on asphalt which might contribute to a higher speed. The narrow design should, in theory, not allow overtaking which should lead the speed of the bicyclists in front	9	The motorized vehicles drive on asphalt which might contribute to a higher speed. The design is narrow design, which should contribute to lower speed. The width allows overtaking, but then the motorized vehicles need to use another suface and lower the speed.	8	The material on the surface should contribute to lower speed. It is narrow which should contribute to low speeds	10	With no speed reducing measures the speed will not be keept on the street except from the fact that there is a sign saying which speed should be.	5
	Road surface	No risk of single accidents due to the road surface	Bicycle single accidents is the largest chare of bicycle accidents.	5	The bicycles might drive on surface that is not aimed for them	7	Might lead to single accidents due to the pavement	8	Might lead to single accidents due to the pavement and the border that will be between the two surfaces if bicylists are overtaking eachother.	8	The road surface will be the same as on a lcoal street today but there might be better maintenance of potholes etc which will make single accidents less common.	6
				50%		80%		80%		90%		55%
Effects on traffic modes	Accessibility effect on bicycles	Improve the accessibility of the bicycles. Detour factor, delay, average speed, width making it available for bicycles to overtake each other	Not improved	0	Improved	10	Improved	10	Improved but less space for the bicyclist compared to the other alternatives which might have effects on overtaking other bicycles. The bike´s space is 1,7 m wide	8	Improved only with the fact that the street is a BSS and that the maintenance will be better.	5
	Nuisance	No nuisance for bicycles such as stopping frequency, slow cycling, traffic nuisance (disturbance of other road users), infra-nuisance (obstacles), no right of way, no of turn offs	Motorized vehciles are many and a nuisance and the bicyclists is not prioritezed at all	0	When bicycles need to drive on the border strip it is a nuisance. Cars behind is a nuisance.	8	If driving close to the pavement the speed of the bicycles needs no be low as well as a nuisence. Overtaking cars are a nuisance.	8	If driving close to the pavement it is a nuisance. Overtaking cars as well	8	The share of motorized vechiles will not change as much, contributin to high nuicens for the bicycles. It wont be a large difference in prioritation since the design is not changed at all to show the rules on the street. The speed will be reduced a littlebit, making the street a bit less nuicance.	1
	Bicyclists satisfaction	Improve the satisfaction of the bicyclists	The bicyclists satisfaction is not enough and the share of bicyclists is not big but it is bigger than on a more drive trough	1	Might be disturbed by the motorized vehicles, but will feel like the "owner of the road" and that the road is designed for the conditions of the road.	9	Might be disturbed by the motorized vehicles, but the vehicles are able to overtake. Feels like the bicycle has a slightly better position then the car	8	Might be disturbed by the motorized vehicles, but the vehicles are able to overtake. Feels like the bicycle has a slightly better position then the car	7	The satisfaction of the bicyclist will not be improved largely, only due to the fact that it is a BSS and that the speed might be lower	4
	The motorized vehicles accessibility	The accessibility for the motorized vehicles should be low, but the availability should remain	The accessibility for motorized vehicles are good on a local street	0	The street is narrow and the motorized vehicles cannot overtake the bicyclists which makes the speed low	10	The street is narrow and the motorized vehicles cannot overtake the bicyclists which makes the speed low	9	The street is narrow which makes the speed low but motorized vehicles can overtake bicylclits	9	The accesibility for the motorized vehicles will be good except that the speed will be reduced minimaly	1
	Pedestrians	Have no negative effect on the accessibility or satisfaction of the pedestrians	Good	10	Good	10	Good	10	Good	10	Good	10
				22%		94%		90%		84%		42%
Economy	Investment cost	Scope of reconstruction	No investment cost is needed	Low	A small border strip is needed	Higher	A medium border strip is needed	Higher	A large border strip is needed	Highest	No investment cost is needed	Low
	Maintenance cost	Scope of maintencence and operation	No extra maintenace cost on the road	Low	Efficient according to space since two kind of vehicles use the same space but the underhåll will be larger since the bicycles require a smoother surface than a motorized vehicles.	Higher	Efficient according to space since two kind of vehicles use the same space but the underhåll will be larger since the bicycles require a smoother surface than a motorized vehicles.	Higher	Efficient according to space since two kind of vehicles use the same space but the underhåll will be larger since the bicycles require a smoother surface than a motorized vehicles. Depending on the material the border strip it might be expensive to maintain this.	Highest	Efficient according to space since two kind of vehicles use the same space but the underhåll will be larger since the bicycles require a smoother surface than a motorized vehicles.	Highest

		One-way BSS for motorized vehicle and two-way BSS for bicycle									
Criteria	**Measures**	**Goal for the criteria**	**Today**		**Border strip on both sides**		**Median**		**Nothing is made to the plan**	
Character of the street	Esthetics	A pleasant urban space for both traffic users and people living there; the design is considered attractive	Depends on the street, but estheticaly it is acceptable but not more	5	Depends on the material. This design does not feel very uncommon	9	Depends on the material. More radical change, but can contribute to a pleasent environment, more of small town street	9	Will not be any improvement to the esthetics on the steet	5
	Urban density	A narrow road that contributes to a urban density	4,5 m	6	3,35 - 4 m, bike area 2,5 m	9	3,35 m, bike area/lane 1,3 m	9	4,5 m	6
	An easy usage	Makes the traffic users know that the traffic should be on the bicyclists conditions and that they are the prioritezed traffic user.	-		The thought of the design is to make the car move to the side and safety stip, but it can be missunderstood so that the bicycles move instead. But the strips a narrow enough so the risk is minimal.	9	how to act is clear	10	no	5
				55%		90%		93%		53%
Environment	Noise/vibrations	No contribution to noise nor vibrations in the surroundings	The amount of motorized vehicles will stay the same and therefore there will be no improvement.	5	only noise and vibrations when overtaking bicycles	8	Noise when overtaking	8	The street will not change in design and therefore will not many traffic users change their behaviour or chose another route. So the contribution to minimize noise will be minimal. And the speed will only be reduced minimaly	5
	Emissions	No emissions on the specific road	Will stay the same	5	positive	10	positive	10	The constribution to no emissions on the road will be minimal. The speed might be a little bit lower than today	5
				50%		90%		90%		50%
Subjective safety	Subjected safety bicy	Bicyclists feel safe when using the BSS	The bicyclist feels quite unsafe and uncomfortable in mixed traffic.	3	might feel forced to the side both when meeting and being overtaken by a car. Will not be disturbed by parked cars	9	might fell forced to the side and drive close to the pavement. Parked cars on the side will make it feel unsafer	8	The subjective safety will be no larger than on a normal local street with mixed traffic today. It will feel like the motorized vehciles own the street and that they are a traffic safety threath to the bicyclists. The sign of the speed might lead to some lower speed on the mot vehicle and will make the bicyclists feel a little bit safer than today.	4
	Pedestrians	Pedestrians not directly effected in a negative way	Ok, since there are sidewalks aimed for the pedestrians	10	Ok, since there are sidewalks aimed for the pedestrians	10	Ok, since there are sidewalks aimed for the pedestrians	10	Ok, since there are sidewalks aimed for the pedestrians	10
				65%		95%		90%		70%
Traffic safety	Keeping the speed	The design of the road contributes to that the speed limit is not exceeded	With no speed reducing measures the speed is not be keept on the street	5	The motorized vehicles drives on asphalt which might contribute to a higher speed. The design is narrow design, which should contribute to lower speed. The width allows overtaking, but then the motorized vehicles need to use another suface and lower the speed	8	The design is narrow design, which should contribute to lower speed. The width allows overtaking, but then the motorized vehicles need to use another suface and lower the speed. The median/border strip in the middle contributes to an unknown situation that lowers the speed	9	With no speed reducing measures the speed will not be keept on the street except from the fact that there is a sign saying which speed should be.	5
	Road surface	No risk of single accidents due to the road surface	Bicycle single accidents is the largest share of bicycle accidents.	5	The bicycles might drive on surface that is not aimed for them	8	Might lead to single accidents due to the pavement or the strip in the middle	5	The road surface will be the same as on a lcoal street today but there might be better maintenance of potholes etc which will make single accidents less common.	6
				50%		80%		70%		55%
Effects on traffic modes	Accessibility effect on	Improve the accessibility of the bicycles. Detour factor, delay, average speed, width making it available for bicycles to overtake each other	Not improved	0	Improved	10	Improved but less space for the bicyclist compared to the other alternatives which might have effects on overtaking other bicycles. The bike infrastructure is 1,3 m/direction	9	Will be improved only with the fact that the street is a BSS and that the maintenance will be better.	5
	Nuisance	No nuisance for bicycles such as stopping frequency, slow cycling, traffic nuisance (disturbance of other road users), infra-nuisance (obstacles), no right of way, no of turn offs	Motorized vehciles are many and a nuisance and the bicyclists is not prioritezed at all	0	the road is wide and there is room for the bicycles. If driving on the border stip it is a nuisance. Meeting and being overtaken by a car is nuisence	7	If driving close to the pavement it is nuisance. Overtaking by cars is some nuisance.	8	The share of motorized vechiles will not change as much, contributin to high nuicens for the bicycles. It wont be a large difference in prioritation since the design is not changed at all to show the rules on the street. The speed will be reduced a littlebit, making the street a bit less nuicance.	1
	Bicyclists satisfaction	Improve the satisfaction of the bicyclists	The bicyclists satisfaction will not be good and the share of bicyclists is not big but it is bigger than on a more drive trough street.	1	Might be disturbed by the motorized vehicles , but will feel like the "owner of the road" and that the road is designed for the conditions of the bicycle since they are allowed in the middle. Motorized vehicles are able to overtake	9	Might be disturbed by the motorized vehicles, but the vehicles are able to overtake. As a bicyclist your space is on the sides which might make you feel like the car is the owner.	7	The satisfaction of the bicyclist will not be improved largely, only due to the fact that it is a BSS and that the speed might be lower	4
	The motorized vehicl	The accessibility for the motorized vehicles should be low, but the availability should remain	The accessibility for motorized vehicles is good on a local street	0	Lower accessibility but overtaking is possible. The design contributes to a lower speed which leads to lower accessibility	9	Lower accessibility but overtaking is possible. The design contributes to a lower speed which leads to lower accessibility	9	The accesibility for the motorized vehicles will be good except that the speed will be reduced minimaly	1
	Pedestrians	Have no negative effect on the accessibility or satisfaction of the pedestrians	Good	10	good	10	good	10	Good	10
				22%		90%		86%		42%
Economy	Investment cost	Scope of reconstruction	No investment cost is needed	Low	Two medium border strips is needed	Highest	Highest	Highest	No investment cost is needed	Low
	Maintenance cost	Scope of maintencence and operation	No extra maintenace cost on the road	Low	Efficient according to space since two kind of vehicles use the same space but the underhåll will be larger since the bicycles require a smoother surface than a motorized vehicles. The border strips on the sides might need som extra maintaining	Higher	Efficient according to space since two kind of vehicles use the same space but the underhåll will be larger since the bicycles require a smoother surface than a motorized vehicles. Depending on the material the border strip it might be expensive to maintain this and different materials can be hard to maintain and keep clean during winter time.	Highest	Efficient according to space since two kind of vehicles use the same space but the underhåll will be larger since the bicycles require a smoother surface than a motorized vehicles.	Higher

Two-way BSS for both motorized vehicle and bicycle

Criteria	Measures	Goal for criteria	Today		Median		Border strip on both sides		Nothing is made to the plan	
Character of the street	Esthetics	A pleasant urban space for both traffic users and people living there; the design is considered attractive	Depends on the street, but estheticaly it is acceptable but not more	5	Depends on the material. More radical change, but can contribute to a pleasent environment, more of small town street	9	Depends on the material. This design is not very uncommon	9	Will not be any improvement to the esthetics on the steet	5
	Urban density	A narrow road that contributes to a urban density	4,5 m	5	4,15 m, bike area/lane 1,7-2,025 m	9	4,15 m, bike area 2,65 m	9	4,5 m	5
	An easy usage	Makes the traffic users know that the traffic should be on the bicyclists conditions and that they are the prioritezed traffic user.	-		how to act is clear	10	The thought of the design is to make the car move to the side and safety stip, but it can be missunderstood so that the bicycles move instead. This could happen in two situations, when meeting a car and when being overtaken	9	No	5
	0	0		50%		93%		90%		50%
Environment	Noise/vibrations	No contribution to noise nor vibrations in the surroundings	The amount of motorized vehicles will stay the same and therefore there will be no improvement.	5	Noise when overtaking	8	Only noise and vibrations when overtaking bicycles and other cars and bicycles	8	The street will not change in design and therefore many traffic users does not change their behaviour or chose another route. So the contribution to minimize noise will be minimal. And the speed will only be reduced minimaly	5
	Emissions	No emissions on the specific road	Stays the same	5	positive	10	positve	10	The constribution to no emissions on the road will be minimal. The speed might be a little bit lower than today	5
				50%		90%		90%		50%
Subjective safety	Subjected safety bicy	Bicyclists feel safe when using the BSS	The bicyclist feels quite unsafe and uncomfortable in mixed traffic.	3	Might feel forced to the side and drive close to the pavement	9	might feel forced to the side both when meeting and being overtaken by a car. Will not be disturbed by parked cars	9	The subjective safety will be no larger than on a normal local street with mixed traffic today. It will feels like the motorized vehciles own the street and that they are a traffic safety threath to the bicyclists. The sign of the speed might lead to some lower speed on the mot vehicle and will make the bicyclists feel a little bit safer than today.	4
	Pedestrians	Pedestrians not directly effected in a negative way	Ok, since there are sidewalks aimed for the pedestrians	10	Ok, since there are sidewalks aimed for the pedestrians	10	Ok, since there are sidewalks aimed for the pedestrians	10	Ok, since there are sidewalks aimed for the pedestrians	10
				65%		95%		95%		70%
Traffic safety	Keeping the speed	The design of the road contributes to that the speed limit is not exceeded	With no speed reducing measures the speed is not keept on the street	5	The material on the surface should contribute to lower speed. It is narrow which should contribute to low speeds	9	The motorized vehicles drives on asphalt which might contribute to a higher speed. The design is narrow design, which should contribute to lower speed. The width allows overtaking, but then the motorized vehicles need to use another suface and lower the speed.	9	With no speed reducing measures the speed will not be keept on the street except from the fact that there is a sign saying which speed should be.	5
	Road surface	No risk of single accidents due to the road surface	Bicycle single accident is the largest chare of bicycle accidents.	5	The bicycles might drive on surface that is not aimed for them and the border between the surface and the pavement if bicylists are overtaking eachother might lead to single accidents.	5	The bicycles might drive on surface that is not aimed for them	8	The road surface will be the same as on a lcoal street today but there might be better maintenance of potholes etc which will make single accidents less common.	6
				50%		70%		85%		55%
Effects on traffic modes	Accessibility effect o	Improve the accessibility of the bicycles. Detour factor, delay, average speed, width making it available for bicycles to overtake each other	Not improved	0	Improved, But overtaking between bicycles is not comfortable	8	Improved	10	Will be improved only with the fact that the street is a BSS and that the maintenance will be better.	5
	Nuisance	No nuisance for bicycles such as stopping frequency, slow cycling, traffic nuisance (disturbance of other road users), infra-nuisance (obstacles), no right of way, no of turn offs	Motorized vehciles are many and a nuisance and the bicyclists is not prioritezed at all	0	If driving close to the pavement it is nuisance. Overtaking by cars is some nuisance.	8	the road is wide and there is room for the bicycles. If driving on the border stip it is a nuisance. Meeting and being overtaken by a car is nuisence	9	Since the share of mot vechiles will not change they will be a nuisance for the bicyclists when they are many and overtaking them. The motorists might show a little bit large respect for the bicyclists with the fact that it is a BSS but it wont be a large difference since the design is not changed at all to show the rules on the street. The minimial reduing of the speed will make it a little bit les nuisance on the street than today	1
	Bicyclists satisfaction	Improve the satisfaction of the bicyclists	The bicyclists satisfaction will not be good and the share of bicyclists is not big but it is bigger than on a more drive trough street.	1	Might be disturbed by the motorized vehicles, but the vehicles are able to overtake. As a bicyclist your space is on the sides which might make you feel like the car is the owner but the infrastructure for the bicyclists is wider than the border strip that is aimed for the car which makes the bicyclists feel prioritezed.	9	Might be disturbed by the motorized vehicles , but will feel like the "owner of the road" and that the road is designed for the conditions of the bicycle since they are allowed in the middle. Motorized vehicles are able to overtake	9	The satisfaction of the bicyclist will not be improved largely only some percent with the fact that it is a BSS and that the speed might be lower.	4
	The motorized vehicl	The accessibility for the motorized vehicles should be low, but the availability should remain	The accessibility for motorized vehicles is good on a local street	0	Lower accessibility but overtaking is possible. The design contributes to a lower speed which leads to lower accessibility. Have to use the border strip at all times	9	Lower accessibility but overtaking is possible. The design contributes to a lower speed which leads to lower accessibility. Have to use borde strip at al times	9	The accesibility for the motorized vehicles will be good except that the speed will be reduced minimaly	1
	Pedestrians	Have no negative effect on the accessibility or satisfaction of the pedestrians	Good	10	Good	10	Good	10	Good	10
				22%		88%		94%		42%
Economy	Investment cost	Scope of reconstruction	No investment cost is needed	Low	A medium border strip is needed in the middle of the street	Higher	Two medium border strip is needed	Highest	No investment cost is needed	Low
	Maintenance cost	Scope of maintencence and operation	No extra maintenace cost on the road	Low	Efficient according to space since two kind of vehicles use the same space but the maintenence and operation will be larger since the bicycles require a smoother surface than a motorized vehicles. Depending on the material the border strip it might be expensive to maintain this.	Highest	Efficient according to space since two kind of vehicles use the same space but the maintenence and operation will be larger since the bicycles require a smoother surface than a motorized vehicles. Depending on the material the border strip it might be expensive to maintain this.	Highest	Efficient according to space since two kind of vehicles use the same space but the maintenence and operation will be larger since the bicycles require a smoother surface than a motorized vehicles.	Higher

Appendix III

Calculations of the widths in the different plan types

As mentioned in Chapter 4 the bicycles have a width of 0,75 m and need an extra fescue space of 0,5 m – 0,8 m depending on the speed of the bicycle. Since the Bicycle Priority Streets are mainly considered for commuters and have a relatively high speed the fescue space that will be considered on the Bicycle Priority Street will be 0,5 m, which is the same as 0,25 m times 2 that is recommended for Space Class A between a moving bicycle and the sidewalk. This means that the bicycle area needs to be 1,25 m for one bicyclist and if comfortable overtaking should take place a width of 2, 5 m is needed.

Designing the width of the Bicycle Priority Street, dimensions for a large car, 1,78 m (set to 1,8 m) has been considered to be the worst case scenario. Trucks dimensions are not considered since this kind of traffic shall be extremely rare on the Bicycle Priority Street. However, the Bicycle Priority Street should always be wide enough for emergency vehicles to fit on the street; 2,55 m.

Space Class C, 0,10 m is needed between a moving car and the sidewalk and has been considered designing the plan of the Bicycle Priority Street as well as 0,35 m between two meeting cars. Also the Space Class C dimension between a meeting car and bicycle, 0,2 m, has been used since some fescue space is already included in the bicyclists need of space. It is mentioned that the space between the two vehicles should be 0,85 m on a road with the speed 30 km/h but since the Bicycle Priority Street should not allow overtaking in a large extent this measure will not be considered.

When a border strip or a median have been used in the plan type they are considered to be used by the motorized vehicles and not the bicyclists. This means that the border strip can be included in the space for the motorized vehicles but not for the bicycles. The border strip has been designed with no larger width than 0,75 m since more would confuse the bicyclists to think the strip is made for them. The mode of transport that needs the widest width in the plan types has dimensioned the width.

The widths for the alternative with no change of the profile have used the dimensions on a 50 km/h street with Space Class B since this is the widest streets assumed to implement the Bicycle Priority Street on and therefore the worst case scenario. On the one way streets it is assumed that the width should have space for both a bicyclists and a car and on the two-way street it is assumed that there should be space for two cars to meet.

The cars wheels are assumed to have a width of about 0,2 m. The bicyclists are not considered to overtake each other when meeting a bicycle.

1 One-way Bicycle Priority Street for both motorized vehicles and bicycles

Today – No change

Dimensions needed:

- Space between curbstone and moving bicycle (0,10 m, Space Class B, 50 km/h)
- Width of the bicycle (0,75 m)
- Space between moving bicycle and car (0,4 m, Space Class B, 50 km/h)
- Width of the car (1,8 m)

- Dimension between moving car and curbstone (0,20 m, Space Class B, 50 km/h)

$$Width = 0{,}10 + 0{,}75 + 0{,}4 + 1{,}8 + 0{,}2 = 3{,}25\ m$$

Border strip on the right side

Dimensions needed:

- Bicycle area that enables overtaking by the bicycles requires the space 1,25*2=2,50 m, Space Class C, 30 km/h
- Border strip should be 0,10 m – 0,75 m

$$Minimum\ width = 2{,}5 + 0{,}10 = 2{,}6\ m$$

$$Maximum\ width = 2{,}5 + 0{,}75 = 3{,}25\ m$$

Border strip on the left side

For car to be able to overtake a bicycle:

- Dimension between moving car and curbstone (0,10 m, Space Class C, 30 km/h)
- Width of the car (1,8 m)
- Space between moving bicycle and car (0,2 m, Space Class C, 30 km/h)
- Comfortable space needed by a bicyclist (1,25 m)

$$Width_{overtaking,car-bicycle} = 0{,}10 + 1{,}8 + 0{,}2 + 1{,}25 = 3{,}35\ m$$

- This gives a border strip of 0,75 m and a bicycle area of 2,6 m

Wide border strip on the left side

For car to be able to overtake a bicycle:

- Dimension between moving car and curbstone (0,10 m, Space Class C, 30 km/h)
- Width of the car (1,8 m)
- Space between moving bicycle and car (0,2 m, Space Class C, 30 km/h)
- Comfortable space needed by a bicyclist (1,25 m)

$$Width_{overtaking,car-bicycle} = 0{,}10 + 1{,}8 + 0{,}2 + 1{,}25 = 3{,}35\ m$$

Border strip

- Width car overtaking bicycle (3,35 m)
- Dimension between moving car and curbstone (0,10 m, Space Class C, 30 km/h)
- Width of the car (1,8 m)
- Width of the car wheels (0,2 m)

$$Width_{border\ strip} = 3{,}35 - (0{,}10 + 1{,}8 - 0{,}20) = 1{,}65\ m$$

- This gives a bicycle area of 1,7 m

2 One-way Bicycle Priority Street for motorized vehicles and two-way for bicycles

Today – No change

Dimension needed:

- Space between two moving cars (0,5 m, Space Class B, 50 km/h)
- 2 x width of the car (1,8 m)
- 2 x dimension between moving car and curbstone (0,20 m, Space Class B, 50 km/h)

$$Width = 0{,}50 + 2 * 1{,}8 + 2 * 0{,}20 = 4{,}5\ m$$

Border strip on both sides

Dimensions needed:

- Bicycle area that enables overtaking and meeting by the bicycles requires the space 1,25*2=2,50 m, Space Class C, 30 km/h

For car to be able to overtake or meeting a bicycle:

- Dimension between moving car and curbstone (0,10 m, Space Class C, 30 km/h)
- Width of the car (1,8 m)
- Space between moving bicycle and car (0,2 m, Space Class C, 30 km/h)
- Comfortable space needed by a bicyclist (1,25 m)

$$Width_{overtaking,car-bicycle} = 0{,}10 + 1{,}8 + 0{,}2 + 1{,}25 = 3{,}35\ m$$

Border strip

- Bicycle area (2,50 m)
- Total width (3,35 m)

$$Minimum\ width\ per\ border\ strip = \frac{3{,}35 - 2{,}50}{2} = 0{,}425\ m$$

Median

Dimension needed:

- Each lane for the bicycles needs at least 1,25 m

For car to be able to overtake or meet a bicycle:

- Dimension between moving car and curbstone (0,10 m, Space Class C, 30 km/h)
- Width of the car (1,8 m)
- Space between moving bicycle and car (0,2 m, Space Class C, 30 km/h)
- Comfortable space needed by a bicyclist (1,25 m)

$$Width_{overtaking,car-bicycle} = 0{,}10 + 1{,}8 + 0{,}2 + 1{,}25 = 3{,}35\ m$$

Width per bicycle lane

- Total width (3,35 m)
- Maximum width of median (0,75 m)

$$Width\ per\ bicycle\ lane = \frac{3{,}35 - 0{,}75}{2} = 1{,}3\ m$$

3 Two-way Bicycle Priority Street for both motorized vehicles and bicycles

Today – No change

Dimension needed:

- Space between two moving cars (0,5 m, Space Class B, 50 km/h)
- 2 x width of the car (1,8 m)
- 2 x dimension between moving car and curbstone (0,20 m, Space Class B, 50 km/h)

$$Width = 0{,}50 + 2 * 1{,}8 + 2 * 0{,}20 = 4{,}5\ m$$

Median

Dimension needed:

- Space between two moving cars (0,35 m, Space Class C, 30 km/h)
- 2 x width of the car (1,8 m)

- 2 x dimension between moving car and curbstone (0,10 m, Space Class C, 30 km/h)

$$Width = 0{,}35 + 2 * 1{,}8 + 2 * 0{,}10 = 4{,}15\ m$$

- Each lane for the bicycles needs at least 1,25 m

Median:

- Median should have a maximum width of 0,75 m and a minimum of 0,10 m

$$0{,}1\ m > Width_{median} < 0{,}75\ m$$

Width per bicycle lane

- Total width (4,15 m)
- Maximum width of median (0,75 m)

$$Width_{min}\ per\ bicycle\ lane = \frac{4{,}15 - 0{,}75}{2} = 1{,}7\ m$$

$$Width_{max}\ per\ bicycle\ lane = \frac{4{,}15 - 0{,}10}{2} = 2{,}025\ m$$

Border strip on both sides

Dimension needed:

- Space between two moving cars (0,35 m, Space Class C, 30 km/h)
- 2 x width of the car (1,8 m)
- 2 x dimension between moving car and curbstone (0,10 m, Space Class C, 30 km/h)

$$Width = 0{,}35 + 2 * 1{,}8 + 2 * 0{,}10 = 4{,}15\ m$$

- Bicycle area that enables overtaking and meeting by the bicycles requires the space 1,25*2=2,50 m (Space Class C, 30 km/h)

Bicycle area

- Total width (4,15 m)
- If a border strip of the maximum 0,75 m is used it gives the bicycle area width of

$$Width_{bicycle} = 4{,}15 - 2 * 0{,}75 = 2,65m$$

Appendix IV

Measures and calculations at Ekedalsgatan

Description of location: Early morning, small raindrops. To be able to be hidden, the speed was measured about 10 meters before a speed bump which probably has impacted the speed and given a speed below maximum speed on the street

Measured Speed (km/h)									
48	36	35	35	35	33	25	32	30	35
26	30	41	45	34	28	35	36	42	40
46	35	40	33	38	36	35	31	38	38
38	38	36	40	43	38	36	35	39	38
36	30	30	37	42	46	31	33	31	27
38	38	33	36	37	41	33	38	38	42
33	37	33	39	37	37	36	37	42	38
39	31	39	33	35	28	39	36	34	35
35	30	32	32	35	27	34	38	36	36
34	28	39	36	34	33	33	30	34	43

Calculation of flow					
Time	**Mot. Veh**	**Bicycle**	**Mot. Veh/h**	**Bicycles/h**	**Share of bicycles**
7:30-7:58	70	32	210	96	46%
7:58-8:08	31	11	186	66	35%
08:08-08:18	25	10	150	60	40%
08:18-08:28	23	12	138	72	52%
		Tot	171	73,5	43%

Speed calculation			
Speed today		**Mean speed**	**35,76**
		85percentil	**39,50**
		15percentil	**30,00**
Speed level		30km/h	30,00
		85percentil	33,13
		15percentil	25,16
		20km/h	20,00
		85percentil	22,09
		15percentil	16,78
		Bicycle speed	16,00
		85percentil	17,67
		15percentil	13,42

Traffic safety calculation		
	x=	2,4
Power model, probability of an accident		
34,42%		
34,42%		
34,42%		
75,22%		
75,22%		
75,22%		
85,49%		
85,49%		
85,49%		

Appendix V

Grading of the value roses in Chapter 6

	Ekedalsgata, one-way	**Allmänna vägen, one-way motorized traffic**	**Allmänna vägen, two-way**
Character of the street, ***how pleasant is the street to use***	A Bicycle Priority Street would give a better character to the street because the speed will be lower and more bicyclists will use the street than today.	Some character will be lost on the street when implementing a Bicycle Priority Street since the cobblestone will be taken away but on the other hand the amount of motorized traffic will be lower.	A Bicycle Priority Street would give a better character to the street because the amount will be lower and more bicyclists will use the street than today.
Subjective safety/security, ***how safe does the road users feel***	The subjective safety/security would be better with a Bicycle Priority Street than today since the speed on the motorized vehicles will be lower and there have to be less off them but they will still be there and give some unsafe feelings.	The subjective safety/security would be better with a Bicycle Priority Street than today since the amount of the motorized vehicles will be lower but they will still be there and give some unsafe feelings.	The subjective safety/security would be better with a Bicycle Priority Street than today since the speed on the motorized vehicles will be lower and there have to be less off them but they will still be there and give some unsafe feelings.
Modal split, ***Is the accessibility/availability low for the motorized vehicle and good for the bicyclists***	A Bicycle Priority Street would give more bicyclists than today and less motorized vehicles than today. Because of lower speeds and speed reducing measures.	A Bicycle Priority Street would give some more bicyclists than today but it is quite a high share already. It would also give less motorized vehicles than today but the share is quite low today since it is a one way street. Because of lower speeds and speed reducing measures.	A Bicycle Priority Street would give some more bicyclists than today but it is quite a high share already. It would also give less motorized vehicles than today but the share is quite low today since it is mostly local motorized traffic on the street. Because of lower speeds and speed reducing measures.
Environmental effects, ***How much noise/vibration and emissions from the traffic on the street***	The Bicycle Priority Street will give more noise/vibrations since there will be uneven surface that the motorized vehicles will use than todays asphalt. On the other hand there will be less motorized vehicles that will give less emission. Also they will drive slower.	The noise and vibration will be much lower when most of the cobblestone is removed at an implementation of a Bicycle Priority Street. Also the emissions will be lower with less traffic.	The Bicycle Priority Street will give more noise/vibrations since there will be uneven surface that the motorized vehicles will use than todays asphalt. On the other hand there will be less motorized vehicles that will give less emission.

Appendix VI

Measures and calculations at Allmänna vägen, North East

Description of location: Good weather. Was hidden behind a car so the speed should be representative

Measured Speed (km/h)										
15	16	16	15	26	15	21	12	20	11	26
20	14	20	12	18	14	20	25	11	20	18
12	22	19	22	11	16	11	14	22	16	13

Calculation of flow						
Calculation of flow southwest, from the city						
	Mot. Veh	Bicycle	Mot. Veh/h	Bicycles/h	Share of bicycles	Share of mot. Veh
16:45-16:55	4	10	24	60	2,5	40%
16:55-17:05	4	21	24	126	5,3	19%
17:05-17:15	3	17	18	102	5,7	18%
17:15-17:25	5	8	30	48	1,6	63%
17:25-17:35	11	20	66	120	1,8	55%
17:35-17:45	3	17	18	102	5,7	18%
17:45-17:55	9	11	54	66	1,2	82%
17:55-18:05	3	12	18	72	4,0	25%
18:05-18:15	3	10	18	60	3,3	30%
		Tot	30	84	2,8	36%

Calculation of flow from northeast, towards the city					
	Mot. Veh	Bicycles	Mot. Veh/h	Bicycles/h	Share of bicycles
16:45-16:55	0	4	0	24	100%
16:55-17:05	0	6	0	36	100%
17:05-17:15	0	4	0	24	100%
17:15-17:25	0	7	0	42	100%
17:25-17:35	0	7	0	42	100%
17:35-17:45	0	3	0	18	100%
17:45-17:55	0	6	0	36	100%
17:55-18:05	0	3	0	18	100%
18:05-18:15	0	4	0	24	100%
		Tot	0	29	100%

Speed calculation				**TS calculation**		
Speed today	**Mean speed**	**17,06**			x=	2,4
	85percentil	**22,00**		Power model, probability of an accident		
	15percentil	**12,00**				
Speed level	30km/h	17,06		0,00%	100,00%	
	85percentil	22,00		100,00%		
	15percentil	12,00		100,00%		

	20km/h	17,06		0,00%	100,00%	
	85percentil	22,00		0,00%		
	15percentil	12,00		0,00%		
	Bicycle speed	16,00		14,28%	85,72%	
	85percentil	20,63		14,28%		
	15percentil	11,25		14,28%		

Appendix VII

Measures and calculations at Allmänna vägen, South West

Description of location: Good weather, a sunny day. The speed was measured between a speed bump and an intersection meaning that the speed might not be the maximum speed. The speed measure instruments were visible meaning that the vehicles might have lowered their speed.

Measured Speed (km/h)											
18	15	12	20	18	17	20	22	15	15	16	13
25	23	20	21	18	18	19	17	15	22	20	19
15	25	16	24	15	17	24	21	16	15	22	16
16	16	17	21	16	20	26	21	15	23	26	27
22	22	19	22	24	17						

Calculation of flow						
Calculation of flow southwest, from the city						
	Mot. Veh	Bicycle	Mot. Veh/h	Bicycles/h	Share of bicycles	Share mot. Veh
16:45-16:55	4	15	24	90	3,8	27%
16:55-17:05	1	9	6	54	9,0	11%
17:05-17:15	5	10	30	60	2,0	50%
17:15-17:25	4	11	24	66	2,8	36%
17:25-17:35	1	13	6	78	13,0	8%
17:35-17:45	6	9	36	54	1,5	67%
		Tot	21	67	3,2	31%

Calculation of flow from northeast, towards the city						
	Mot. Veh	Bicycle	Mot. Veh/h	Bicycles/h	Share of bicycles	Share of mot. Veh
16:45-16:55	13	2	78	12	15%	6,5
16:55-17:05	15	10	90	60	67%	1,5
17:05-17:15	17	11	102	66	65%	1,5
17:15-17:25	7	13	42	78	186%	0,5
17:25-17:35	15	9	90	54	60%	1,7
17:35-17:45	17	10	102	60	59%	1,7
		Tot	84	55	65%	1,5

Speed calculation		
Speed today	**Mean speed**	**19,15**
	85percentil	**23,75**
	15percentil	**15,00**
Speed level	30km/h	19,15
	85percentil	23,75
	15percentil	15,00

Traffic safety calculation	
TS calculations	x=2,4
Power model, probability of an accident	
0,00%	100,00%
0,00%	
0,00%	

	20km/h	19,15		0,00%	100,00%
	85percentil	23,75		0,00%	
	15percentil	15,00		0,00%	
	Bicycle speed	16,00		35,02%	64,98%
	85percentil	19,85		35,02%	
	15percentil	12,53		35,02%	