A study of cyclists' need for an Intelligent Transport System (ITS)

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

ANDREAS RUTGERSSON

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover:
Picture of a bicycle traffic light (303cycling, 2011)

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ABSTRACT

The aim with this master thesis is to make linkages between the cyclists' need and the available intelligent transport systems (ITS). However, this report will not try to estimate the most important needs because people have different needs and they are prioritized differently. Government and NGOs websites, literature and interviews with experts in the fields have been the main source of information. Investments in infrastructure and campaigns are among the means to increase the bicycling population. ITS can make the current traffic system more efficient by providing travellers with additional information about the traffic situation. Another intention is to change the behaviour of motorists to start using a bicycle to their destination. The Swedish Transport Administration uses the four-stage-process as the main working strategy and the first two steps highlights an attitude change and promotes environmental travel choices that is in line with ITS intentions.

This paper has made an in-depth look into the physical development of commuting cyclists (7 to 65+ years), accident statistics as well as comments from bicyclists. Current intelligent bicycling systems have been looked into as well as a brief outlook on future systems. The analysis describes six basic transportation needs[1] of the bicyclists and the connection to the intelligent systems. The conclusion of this report is that intelligent transport systems are an extra layer of effectiveness on the top off the physical infrastructure. Smartphone applications can play a major role in the future traffic system in terms of route planning-, service-, and remove disturbances applications. Disturbance management will play a large part to enhance the current bicycle lanes. The 'Bicycle sharing' system can be a platform for further development to add new ITS systems on in a large scale. An example is to make every bicycle in the sharing system to an electrical assisted bicycle and this will improve the comfort, travel time and range. Green Wave and motion detecting systems is part of the infrastructure and these systems give priority to bicyclists at intersections. In the end, biggest problem people have is with the non-connected road network and the road surface due to slipperiness.

KEY WORDS: ITS, Intelligent transport system, Cyclist, Bicyclist, Needs, Accidents, opinions, connections, Information, four-stage-process.

[1] Connectivity, Accessibility, Safety, Comfort, Information and Time

Contents

Preface

This master's thesis has been written during January 2013 and May 2013 under the Department of Civil and Environmental Engineering, Division of GeoEngeering, Road and Traffic Research Group at Chalmers University of Technology, Sweden. Karin Bäfver (at Sweco) and I coined the project during a meting with Peter von Heidenstam (at the Swedish Transport Administration) were the purpose and limitation was created. The thesis was carried out at the Division of Intelligent Transport Systems at Sweco Göteborg, under the supervision of Karin Bäfver. Interviews and meetings with experts in the field were carried out during the time period above. The examiner and academic supervisor of this master thesis was Gunnar Lannér, Senior Lecturer at the Division of GeoEngeneering.

I would first like to thank Karin Bäfver for believing in me and give me a foundation and opportunity to write the report at the Division of ITS at Sweco. I also want to thank the personnel of the Department of Traffic at Sweco for there for their broad and deep understanding of the needs of bicycling and ITS. In addition, a special thanks to Andreas Larsson; that he had taken upon himself to provide me with valuable information during the time of the project. I would also like to acknowledge the support from Peter von Heidenstam and the staff at the Swedish Transport Administration and their contribution to this thesis. In addition, I want to thank Gunnar Lannér for constructive criticism and academic guidance to complete this report.

Finally I would express my appreciation to Andrea Nilsson to keep believing in me and pushing me to have the strength to finish this master thesis.

Göteborg May 2013

Andreas Rutgersson

1 Background

The bicycle is an invention that has been used as a mean of transport for a long time but has become displaced due to the increasing vehicle traffic. The views on bicycling have afterwards been seen as an old technology and the bicycle have thereafter been given a lower priority in the traffic system in favour of car. In addition, the lower priority meant even worse conditions for cyclists and made the bike to a less attractive choice. Furthermore, the bicycle has then been seen as a recreational tool and not a real transport tool (SvD, 2013).

Today are the majority of work-related travels done by car or public transport, but in recent years have bicycle traffic grown rapidly. Investments towards a safe and accessible traffic system are therefore required. Intelligent transport systems can be a cost effective alternative to accomplish the expressed transport goals.

ITS have been used in our traffic systems since the first traffic light, but have mainly focused on the vehicle traffic. The Swedish Transport Administration intend to improve the awareness of ITS as a alternative to expensive physical traffic investments in line with the Four-Stage-Process[2] (Trafikverket, 2011a). The aim of an intelligent transport system is to improve the traffic flow and traffic safety by directing traffic and influence the traveller's behaviour to ensure congestion free roads and traffic safety.

1.1 Purpose

The aim of this report is to map out the bicyclists needs as well as investigate relevant intelligent transport systems and make linkages between the two. The relevant connections between the two subjects will increase the knowledge and understanding between bicycling and ITS.

1.2 Limitations

The master thesis purpose is to make a connection between the needs of the bicyclists and current ITS solution. The study will have a global perimeter but will focus on bicyclists needs in urban environments in a seasonal climate with warm and cold periods. The bicyclists are school children between 7 and 13, commuters to work and university (18-65) and commuting senior citizens (65+). An in-depths study of the current ITS systems for bicyclists will be done. A minor outlook on future ITS systems will de looked at briefly but will not be included in the analysis. The ITS systems on the verge are ether in the development- or prototype stage. There are several smartphone and web based applications that can enhance the traffic system. However, this thesis will only look into the services of the applications and explain the functions due to the large number of software products. The thesis will only study the bicyclist's physical development, accident statistics and bicyclists opinions. However, this report will not make an evaluation of the most important needs because all bicyclists have different needs and they are prioritized differently; therefore are all needs on an equal basis.

[2] Each step in the Four-Stage-Process covers various aspects and stages of development in the Swedish (See Appendix A)

1.3 Method

Information has been gathered mainly from Internet and literature sources as well as interviews with people with technical expertise. Furthermore, the information from the Internet is based on websites from the Swedish Transport Administration, Bicycle NGOs, Local road authorities as well as company websites in the ITS cycling field. Analysis of 1400+ comments of bicyclist's opinions has been done thru government and bicycling communities websites. The ITS system information comes from government websites or product descriptions from different company websites.

1.4 Readers guide

Chapter 1 introduces the thesis with its background, purpose, limitations and the method used.

Chapter 2 gives the reader and an outlook of political and public support for increased bicycling.

Chapter 3 provides the reader with background information about ITS and the four-stage-process that is heavily emphasized by the Swedish Transport Administration. In addition, a life-cycle analysis process and aspects to keep in-mind are also presented.

Chapter 4 defines the different physical conditions of the bicyclists and accident statistics. Furthermore, this chapter includes all the opinions that have been presented during the period.

Chapter 5 maps out all the current intelligent transport system for bicyclists and divide them into themes of bicycle-based systems, managing traffic, monitoring traffic, providing information and systems on the verge.

Chapter 6 defines the linkages between the need that have been found in chapter 4 and all the current ITS systems that has been found in chapter 5.

Chapter 7 is the part were the discussion about the analysis takes place and it brings up all the possibilities and impossibilities of the ITS systems to meet the needs of the bicyclists.

Chapter 8 concludes the thesis with the key discoveries.

2 OUTLOOK ON BICYCLING

The European Union (EU) has stated that ”By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road casualties by 2020. Make sure that the EU is a world leader in safety and security of transport in all modes of transport” (ETSC, 2012)[3]. In the year 2009 were about 7% of all fatalities in the union bicycle accidents and deaths has increased slightly since 2000 (SafeCycle, 2012). The countries that have made bicycle infrastructure investments tend to have the lowest number of mortalities and a higher number of cyclists. The vision of the union is to build a competitive transport system that will increase mobility as well as cut Europe's carbon emissions from transport with 60% by the year 2050 (European Commision, 2011).

The Swedish government intends to improve the conditions of choosing public transport and bicycling in a government bill from 2008[4] (Näringsdepartementet, 2008). The government has also expressed interest in an increased use of IT for road safety, increase public health and scrap the dependency of fossil fuels by 2030 (Näringsdepartementet, 2009). The community benefits of bicycling are increased public health and reduction of carbon dioxide emissions, pollution and noise. The Swedish Transport Administration has a vision that no traveller shall be killed or be seriously injured (Trafikverket, 2013). This vision does not only include motorized vehicle drivers but also bicyclists.

The City of Stockholm has set a goal to increase the number of trips with bike as well as improve the traffic safety of those trips. One of the city's visions is to have a well working cycling network by the year 2030 to make it easy to commute to work (Stockholm Stad , 2012). One of the goals is that 15% of all trips during rush hour shall be form bicycling by the year 2030.

The second largest urban area in Sweden is Gothenburg were 10% of all trips are done by bike today (Trafikkontoret Göteborg, 2011). A survey conducted by the local traffic office shows that there are 105 000 trips per day and half of them are a trip between home and work. Bicycling has been prioritized in the city and more infrastructure investment will be done in the next decade due to the West Swedish Agreement. The investments will increase the proportion of bicycle commuting in the city of Gothenburg.

Bicycling has always been an attractive mean of transport in the south part of Sweden. The City of Malmö and the capital of Denmark, Copenhagen, have formed a joined cycling plan to strengthen the territory as cycling region (ÖSCR, 2013). The municipality of Malmö have expressed that the city want to increase the number of cyclist from todays 23% to 30% by the year 2018 (Region Skåne, 2012).

In conclusion the European Union (EU) and every level of government in Sweden has a desire to increase the number of bicyclist in the near future by investments in infrastructure and campaigns.

[3] European Transport Safety Council

[4] Government proposition: 2008/09:93

3 OUTLOOK ON ITS

3.1 Background – What is ITS

The Swedish Traffic Administration defines intelligent transport system as a way to make the traffic system more efficient by providing travellers with accessible and understandable information about their traffic environment. These improvements in the traffic system are also intended to change the behaviour of motorist to start using a bicycle to their destination. The systems used today are mostly tailor made solution that is applied to a specific traffic situation (Trafikverket, 2011a). ITS require electricity and a communications antenna to work properly compare to physical improvements. However, a few ITS systems does not require any communications equipment. In addition, damages by weather and theft can be a problem for the systems but the systems are more cost effective and can therefore be a viable alternative. Intelligent transport systems can contribute to make the traffic situation better in an alternative way compare to physical improvements. ITS follows all traffic legislation due to the fact that it is an equal part of the traffic system as physical improvements (Trafikverket, 2011a).

The innovations will make the system more efficient, seamless and simpler (European Commission, 2012). The systems combine computers, electronics, satellites and sensors where the main goal is to integrate it to the existing infrastructure to create new services.

3.2 The Four-Stage-Process

The Swedish Transport Administration has a wide range of projects and the commonality between them is the four-stage-process as the main working strategy (see appendix A) (Trafikverket, 2012). Each step in the four-stage principle covers various aspects and stages of the development of transport and infrastructure. Sustainable development is important for the global society and therefore have sustainable travel been emphasized on the first two steps. The first two steps highlights an attitude change and promotes eco-friendly travel choices. The main goal with the Four-Stage-Process for the Swedish Transport Administration is to maintain an on-going discussion about how sustainable travel can be optimized as far as possible.

1. **Re-think**

   The fist step involves the process of thinking about the end affects, on the choice of transportation and the need of transport, before implementing intended action.

2. **Optimize**

   The second step is to implement measures, which lead to a more efficient use of existing infrastructure.

3. **Rebuild**

   The third step, if necessary, involves limited redevelopment.

4. **Build new**

   The fourth step, if the need can’t be met in the previous three steps, involves new investments and/or major reconstruction measures.

3.3 Life-cycle analysis

The general life-cycle (see figure 1 below) process of an intelligent transport systems starts with a need or requirement that have been identified. It is important to recognize and understand the need for improvement in the traffic system before an intelligent transport system is implemented. The next stage is to implement a suitable system at the specific location in the intended traffic situation. There should not be any confusion from the bicyclists what the intention of the system is otherwise should the system be reconsidered to be removed and/or changed. Furthermore, by informing the bicyclist about the situation will a mutual understanding of the solution will be fulfilled. Furthermore, the systems will provide information in exchange for electricity and part replacements during its lifetime. In addition, this will require operation and maintenance support of the system by the service provider. The last stage of the life cycle is to evaluate the ITS investment when the system have been operational for a period of time. The evaluations purpose is to determine if the system has the desired effect on the traffic; otherwise should the system be removed and be placed at another location. Additionally, benefits can be seen during a long-term study and therefore must the local road authorities be committed for it to be successful. A review during a long-time will also show if the system is sustainable over time otherwise should the local road authorities remove the system. It is therefore utterly important to have a committed local traffic office to ensure a long-term success (Trafikverket, 2011a).

Figure 1: Illustration of the life-cycle analysis for a general intelligent transport system

4 THE BICYCLISTS

4.1 Description of the selected bicyclists

For simplicity have the categories below been selected and they are based on people's age because it's crucial for their physical development and lifestyle. A definition of a bicyclist is a person that uses a bike one to three times per month according to the Traffic office of Gothenburg City (Trafikkontoret Göteborg, 2011).

4.1.1 Commuters to school (7 to 13 years)

In order to understand children's development is it important to understand the physical, cognitive and social development of children to determine their needs in traffic. The following is therefore a brief description of the children's development (between 7 and 13 years) until he/she can travel in traffic safely as an individual.

When kids are around seven years old are they growing about six centimetres and about two kilograms per year (Karlsson, 2003). A normal seven year old weighs about 20 kg and is about 1,2 meters tall. Furthermore, the complex skills of their physical and mobility development are starting to progress. In their psychological development can kids at this age discuss everything they encounter and perceive, understand logical principles as long as they can be linked to concrete things or events, describe their thinking, see something from a different perspective and to take someone else's role. Still, the child has difficulties to reason abstractly and need to have the concrete reality in front of them to help them understand. In addition, kids around seven years old tend to explain their actions based on the situation here-and-now compare to a eight year old that can as good as an adult to process information. However, kids at this age lacks experience in traffic and they have a limited vocabulary, which means that they are worse than adults in unfamiliar situations to observe, remember and react to events. The Swedish Transport Administration recommends; children between 11 and 12 years can only be allowed to cycle alone in traffic. However, smaller children can navigate in simple traffic situations. Children learn to navigate and move safely in traffic if they can cycle to school by themselves but that puts a demand to construct a safe traffic system from the beginning.

Children at the age of 12-13 years old are going thru major physical changes and even more change in growth during the teenage years. A key difference at this stage compared to the previous is that teenagers can think logical. By comparison can a teenager think of alternatives and phenomena that are not present, set up hypotheses and systematically go through them, think about their own thinking and go beyond existing and conventional frames and borders. Another important development is that teens become more independent of their parents and doing more things themselves, which increases this independence (Karlsson, 2003).

4.1.2 Commuters to work or university (18 to 65 years)

A commuting cyclist is a person between 18 and 65 years old and uses his/her bike one to three times a month. The physical development of these people is in their prime age and only personal physical/mental disadvantages can have effect. This category has a large diversity of cycling types due to its large spectrum of people. However, there are two categories that can be defined (Traffikkontoret, 2012a). First, there is the type of bicyclist that uses the bike to work every day in all weather. They see their commuting as an opportunity to exercise and a way to save time and money. The second type uses their bike to get to work and shopping if there is a good weather otherwise they choose another way of transport.

University students are generally a well-educated group of people that are aware of the modern conditions and are eager to learn and change their behaviour (Trafikkontoret Göteborg, 2012e). A cycling student is a person between 18-30 years old that uses their bike one to three times a month or more to get to their respective school. Bicycling can be a part of their identity/lifestyle that symbolizes their independence to travel anywhere. In addition, they travel generally by bike as a complement to public transport due to economic and comfort incentives. The bicycle is also seen as a way to exercise and to relax and therefore improve their health and the environment.

4.1.3 Commuting senior citizens (65+ years)

Senior citizens are a segment of the population that is 65 years or older. Many seniors have had a car for the larger part of their life and it is therefore a habit that they continue to use the car instead of start bicycling (Trafikkontoret Göteborg, 2012b). According to (Spolander, 2007) are 40% of seniors involved in traffic-deaths due to their frail physical fitness and falling accidents on the bike ride. The probability of injury are higher for seniors compare to the rest of the population, were the probability for death is five times higher for 65-74 year olds and ten times higher for 75+ year olds. This can be explained by the kinetic energy and height of the fall that makes it two the three times more dangerous compare to a pedestrian fall. In addition, heavy breaking downhill or at fast speeds can be dangerous if the person falls of the bike. Furthermore, senior citizens have generally a passive lifestyle were they stopping using the bike relative early and where a lifestyle change could improve their wellbeing. When people get older, the body intends to lack the balance, agility and physical strength with increased age (Spolander, 2007).

4.2 Accidents

A recent study conducted by the Swedish insurance company Folksam illustrates that the bicycling accidents have the largest proportion with nearly half of the injuries that lead to medical invalidity[5] (see figure 2) (FOLKSAM, 2012). A more in-depth study of the statistics can be seen in appendix B. The cycling accidents are approximately six times larger or more compare to the others, except for car related injuries. The car related injuries are the second largest category that got permanent disabilities with 28% of the total. The study has been based upon information from the insurance company Folksam and data from hospital records. According to the report have the knowledge of the large proportion of injuries been unknown because previous reports has been only based on reports from the Swedish Police. In addition, one of the conclusions of this recent report from Folksam shows that there is six to seven more bike injuries compare to the police reports.

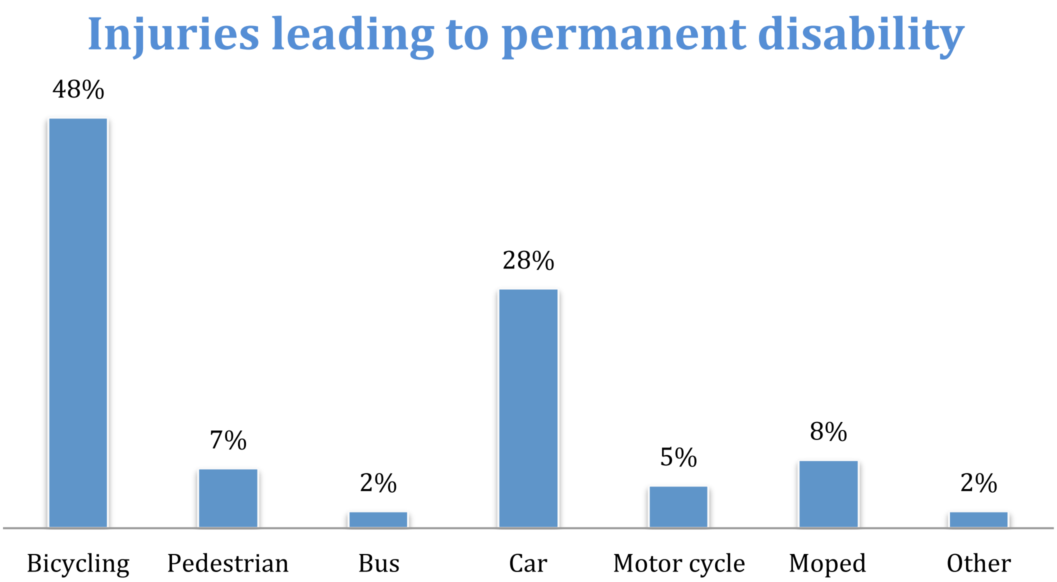

Figure 2: Percentage of traffic injuries leading to permanent disability (medical invalidity) based on data from emergency hospitals in nine large cities in Sweden between 2010-2011 (FOLKSAM, 2012)

Furthermore, as can be seen in figure 3 are single accidents the lion part of the injuries with 71% followed by collision between bike and motor vehicles with 18,3%. The third largest category are collisions between two bicyclists that occurs 7,1% of the total number of accidents. Bicyclist between 15-24 years old are the dominant demographic when it comes to bike-motor vehicle collisions. The study shows no clear division between the sexes when it comes to motor vehicle conflicts. Teenagers and kids are the dominant demographic for single accidents were men are over repressive. Furthermore, seniors are the dominant demographic at serious injuries to traffic related deaths (FOLKSAM, 2012).

[5] Physical and/or mental disability for any reason and without regard to the claimant's occupation, hobbies or other special circumstances (Sveriges försäkringsförbund, 2004).

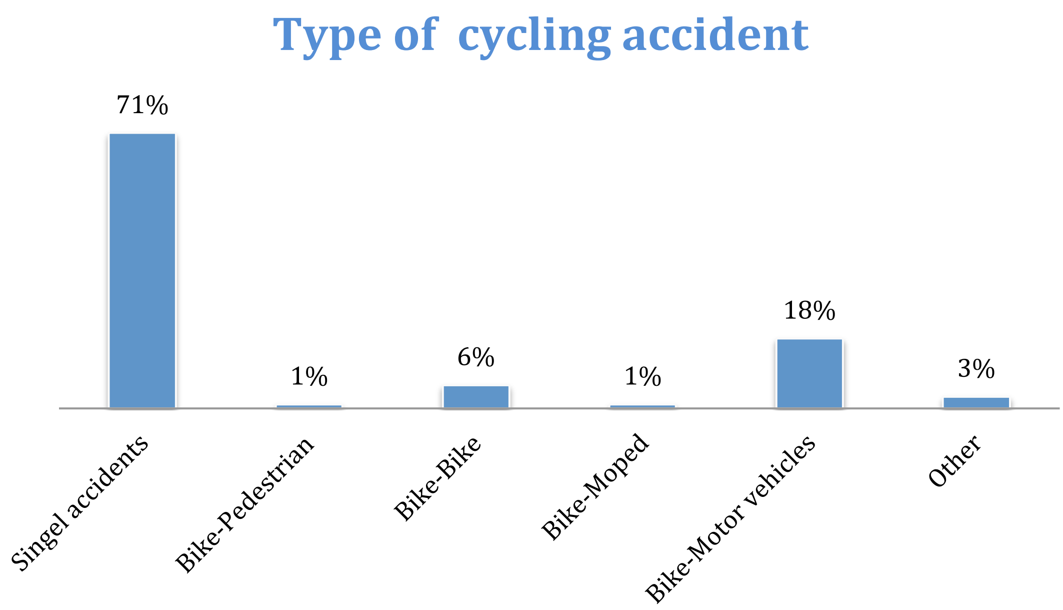

Figure 3: Illustration of the type of cycling accident (Niska, 2013)

Single Accidents

The largest posts when it comes to single accidents are related to operation and maintenance (27 %) and the bicyclist's interaction with the bike (27%) as can be seen in figure 4. One in five injuries are connected with the road design as the main reason for the accident. Behaviour and state of mind stand for 14% percent of the misfortunes were alcohol consumption, play or other distractions may be a factor. Moreover, just over one in ten accidents involve injuries due to interactions with other bicyclists (Niska, 2013).

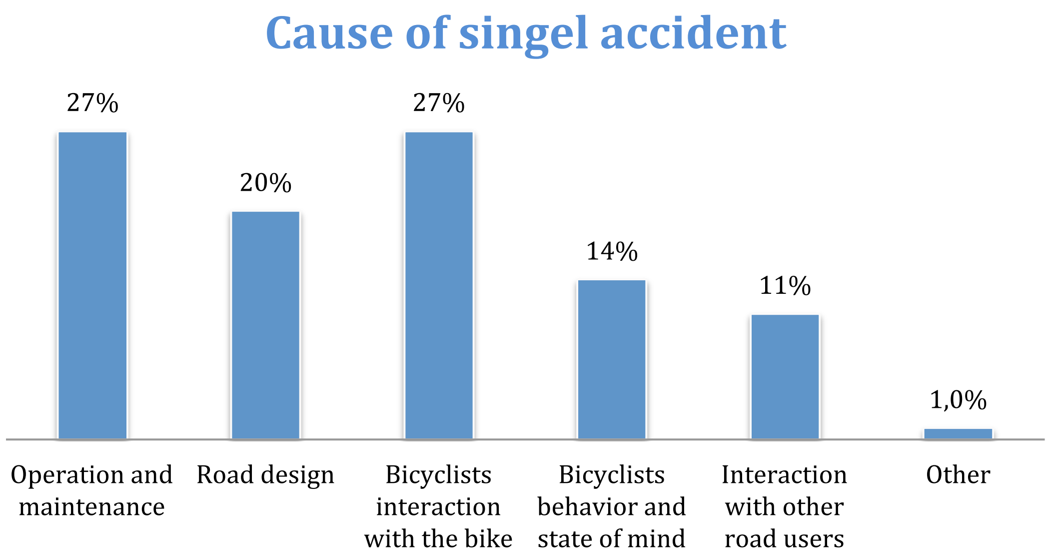

Figure 4: The main reason for single accidents (Niska, 2013).

A look into the section *operation and maintenance* we see that snow/ice on the road surface is the largest part with almost half of the single accidents (see figure 5). Additionally, sand/gravel are the second largest source of serious injuries. The quality of the road surface is also causing problems due to the uneven surface as well as collision with temporary objects such as branches and road construction blocks etc. (Niska, 2013).

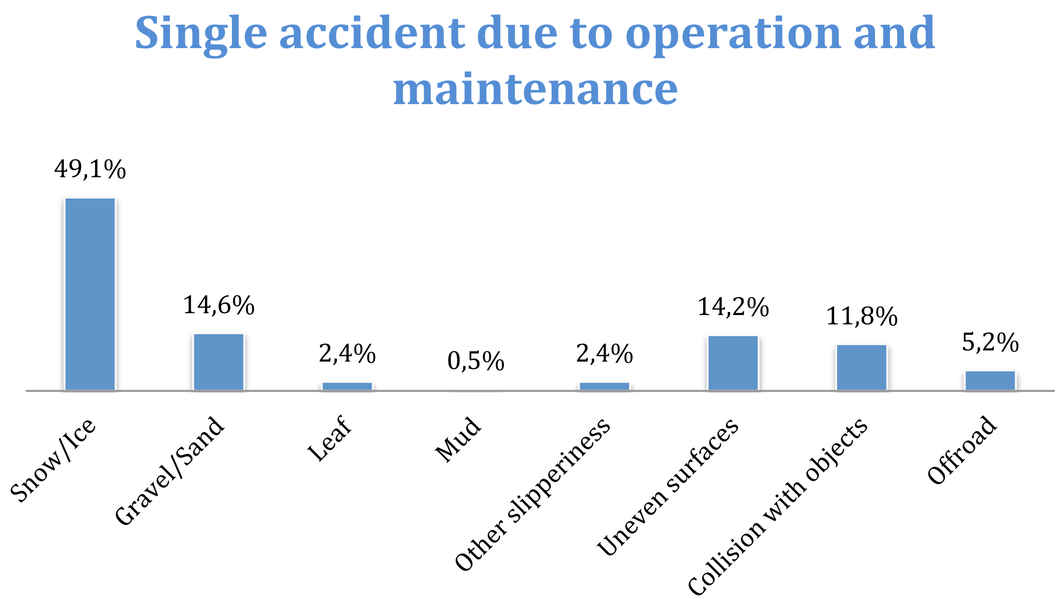

Figure 5: Number of people who have been seriously injured related to operation and maintenance (Niska, 2013).

The major issues with the *bicyclist's interaction with bike* are the jump on/off the bicycle (56%) that causes single accidents often in combination with something that is stuck in the wheel (Niska, 2013). However, some bicyclists have noted that an item that got stuck in their wheel were their main reason for falling (12,6%). The items that got stuck could be a garment or any object, which they transported. Defected bicycles are another problem that causes accidents (20%). People have also reported that their single accident was cause by the need to do a grinding halt with their front handbrake that caused them to fall (9,8%). Lastly is all the other sort of breaking situation that causes accidents (1,6%).

The third greatest cause of single accidents are *road design* where difficulties involve problems with sudden height differences as curbstones or similar (55%). Also, people also have problems with concrete blocks, boom barriers (40%) and some have been reported to be stuck in tram-tracks that caused the falling accident (5%). Most bicyclists have reported that their accident occurred during a downhill. Additionally, about 1/3 said that the injury was caused when they tried to turn in a curve. However, only a few people said that darkness was the reason why they fell of their bike.

When it comes accidents due to *bicyclists behaviour and state of mind* where they lost control over the bicycle that was not influences by any external forces. Most of these cases were the result of to high speed or that the person was influenced by alcohol. People also reported that they fell during play. Also, bicyclists were seriously injured when they rode their bike with their dog and the dog stopped, took off in another direction or similar (Niska, 2013). Furthermore, accident that are the result of *interactions with other road users* were caused when the cyclists had to make way for vehicle traffic, mopeds, other cyclists, pedestrians and dogs (Niska, 2013).

Bike-Motor vehicle accidents

Furthermore, the second largest type of accident is collisions between motor vehicles and bicycles were 76,7% of the total Bike-Vehicle injuries is road-crossing situations (Försäkringsbolaget If, 2012). Moreover, dangerous road-crossings are with and without a bike lane as well as exit / entrance driveways for cars. According to the report are unclear rules and misconceptions the main source of many accidents.

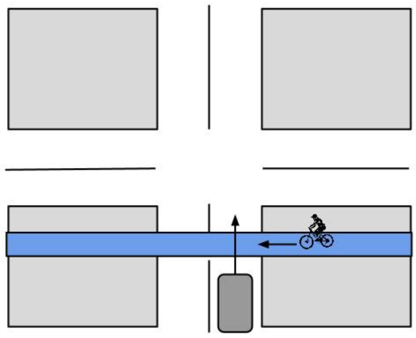

Figure 6: Illustration of a potential traffic accident.

In addition, at intersections between motor vehicle and bicyclists were the cyclist comes from the right are one of the most common type of accidents as can be seen in figure 6.

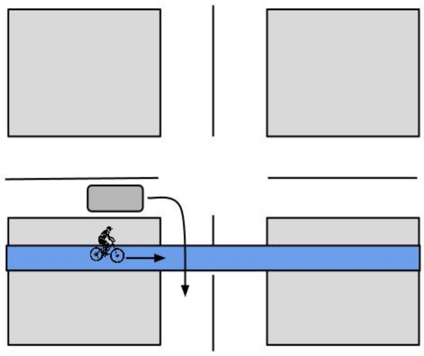

Figure 7: Illustration of a potential traffic accident.

Also, conflicts between vehicle traffic and bicyclists are were the vehicle turns right and the cyclist go straight as can be seen in figure 7 are common in the SAFER[6] report (Försäkringsbolaget If, 2012).

In clarity, the law reads: "Cyclists coming from a cycle lane must give way when crossing a road. This applies even if there is an unattended bicycle crossing. Motorists should adjust the speed to an unattended bicycle crossing, so that there is no danger to cyclists who are out on the bike crossing" (Transportstyrelsen, 2009).

However, about 8% of the accidents are in traffic light intersections were the most common conflict are when the vehicle turn when both travellers has green light (Försäkringsbolaget If, 2012).

Conflicts between cyclists and vehicles are also when they travel in the same direction and that stands for 10% of the total bike-vehicle accidents (Försäkringsbolaget If, 2012). The issues between the two above are; cyclist has been hit from behind, car with trailer or caravan drives too close and lane changing.

Head-on collisions are about 3% of the total bike-vehicle accidents and the issue is when a bicyclist due a shortcut in a curve and this is often done by teenagers and kids (Försäkringsbolaget If, 2012).

Additionally, about 4-5% of the bike-vehicle accidents are when a parked car opens a car door and a cyclist hits it. However, this is a problem that is located in city areas were seniors and women are the most affected (Försäkringsbolaget If, 2012).

[6] Vehicle and Traffic safety research center at Chalmers

Location of injuries

80% of all injuries are legs and arms related were arm/shoulders are the most injured (FOLKSAM, 2012). Helmets do not protect these injuries and therefore could a cycling jacket be of importance. The bicycle jacket can absorb the energy of the fall. Additionally, the bicycling injuries that led to medical invalidity are connected to: 10 % for head/face, 50% for arms, 28% for legs, 5% for the back, 6% for the neck and 1% for the chest/stomach as can be seen in figure 8. Accidents occur during the summer period with additional spikes in September and May (Försäkringsbolaget If, 2012). In addition, most injuries occur between 7-8 o'clock as well as around 16 o'clock and this is during peak hours in traffic. The lion part of the accidents occur in urban areas were the speed limit is 50 km/h or less. Also, most cyclist gets injured during daylight (80%) and at a good whether condition (about 70%).

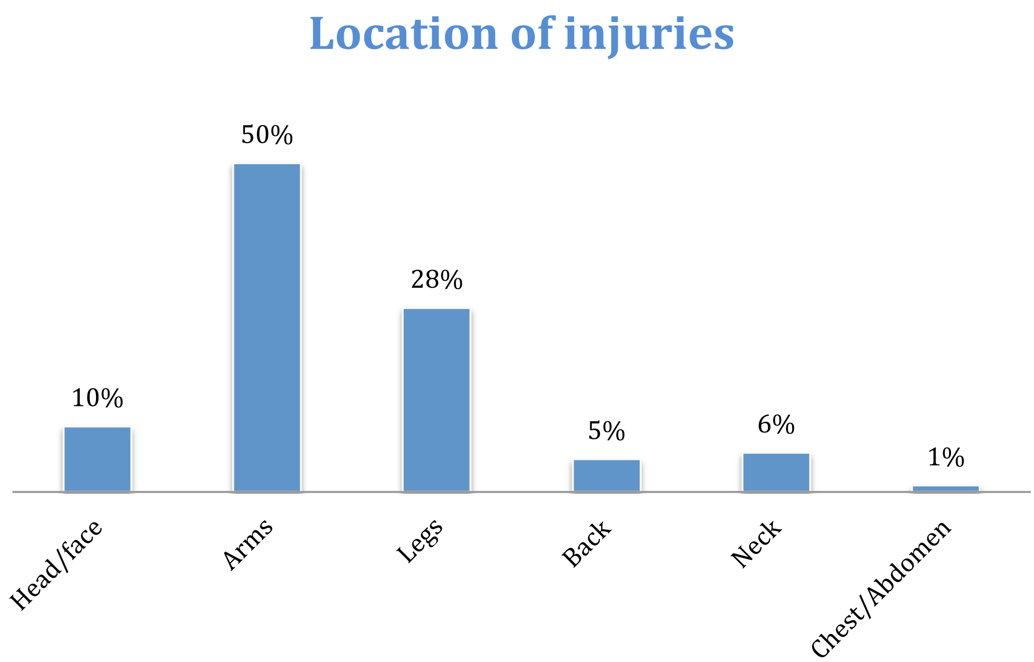

Figure 8: Shares of cycling injuries that led to medical invalidity (FOLKSAM, 2012)

Traffic related deaths

According to (Försäkringsbolaget If, 2012) is 7% (2011) of all traffic related death in Sweden bicyclist. During the first part of the part of the five year period between 2007 and 2008 were about 30 persons killed every year, but during the last three years between 2009 and 2011 have the number of kills been reduced to about 20 persons per year as can be seen in figure 9 (Niska, 2013).

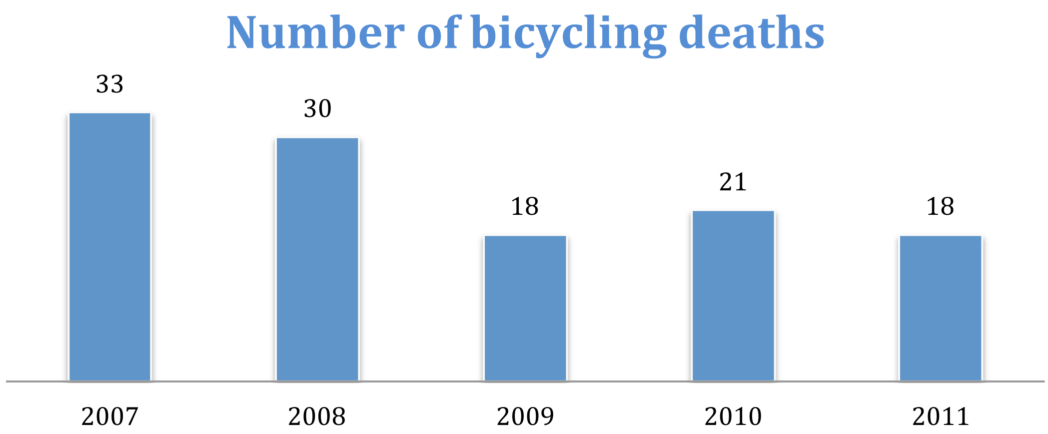

Figure 9: Number of killed cyclists between the years 2007 and 2011 (Niska, 2013)

However, during the five-year period was 120 persons killed and the lion part of the fatal accident was between bicyclists and motorized vehicles followed by single accidents (see figure 10). Furthermore, of the 23 persons who were killed in single accident were 16 men and seven women. Also, only four persons were under the age of 50 years and almost half of the killed were 65+ years. In summary, death by single accident is more common with the senior citizens over 65 years. Injuries to the skull were represented in 70% of the single accident cases and only 3 of 23 persons were using a helmet. In addition, only one person with bike helmet died in a single accident due to high speed down hill and collision with a curbstone. The majority of the accident happened during leisure time compare to work related trips. Seven persons tested positive for alcohol occurrence (between 1,05 and 3 per mille), nine tested negative and the rest are unknown. In addition, a small number of people had traces of pharmaceutical substances in terms of painkillers and local anaesthesia. Road design can also be considered a contributing or primary cause of the single accident deaths where alcohol intake could not be determined (Niska, 2013).

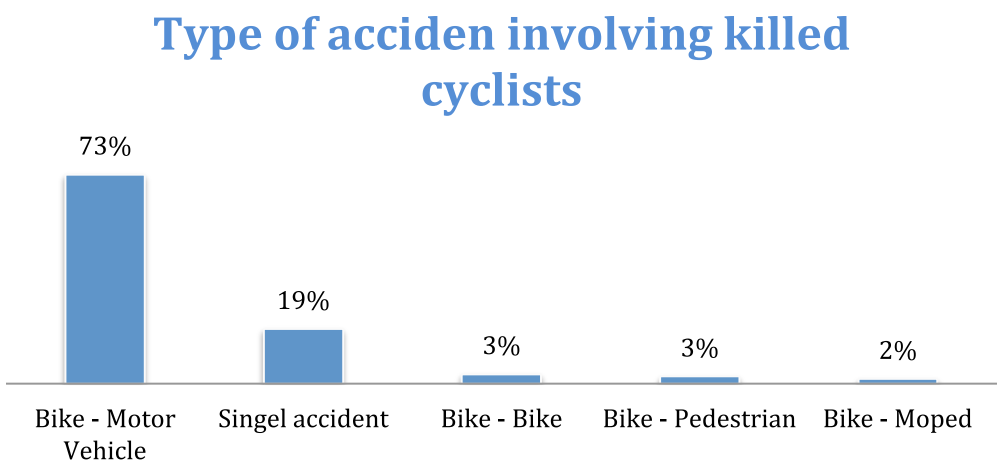

Figure 10: Type of accident involving killed bicyclists, between 2007-2001 (Niska, 2013)

4.3 Bicyclists opinions

The bicycle is an environmental friendly mode of transportation that does not contribute to pollution compare to vehicle traffic that emits damaging particles and gases from their combustion (Trafikkontoret Göteborg, 2012b). However, people are indirectly affected because people ride beside the main roads in most cases. The bike is an in-expensive alternative that is easy, flexible and is relatively quick in cities due to shortcuts. Furthermore, other advantages are a door-to-door trip with easy parking and no need to take public transport schedules into account. The population around 18-29 years old sees the bike as a mean of transport compare to the senior population that uses it more as a recreational tool. However, the bicycling community has expressed ideas to improvements that are the following:

The road authorities must give bicycling network a higher priority and design the next bike lanes for future bicycling flows. The bicycling community has therefore asked that the road manager plan long-term (5-10+ years) solutions over party lines to get the best solution (Uppsala Kommun, 2012). A selected group of advisors in the field should be used for support. Additionally, the local road authorities must design the network for different speeds because bicyclists travel around 7-8 km/h and/or between 15-25 km/h (Trafikkontoret Göteborgs Stad, 2013). Standardization of intersections and roundabouts with for easy understanding for both the vehicle traffic and bicyclists is requested (Uppsala Kommun, 2012).

Awareness campaigns have been asked for that focus on safety, public health, behaviour and traffic rules (Uppsala Kommun, 2012). Furthermore, the bicycling community wants campaigns that increase the understanding of reflective vests or distribute free studded tires etc. for the population. Promotional bicycling competitions and races can also be arranged (Trafikkontoret Göteborgs Stad, 2013). The local traffic office can collaborate with workplaces to get their employees to bike more (Uppsala Kommun, 2012). Furthermore, have promotional signs along the roadway as incentives for people to star using their bikes been asked for (Trafikkontoret Göteborgs Stad, 2013). Some suggestions are: “Thanks for biking”, “The roadway is designed for our environmental heroes - the cyclists”, “You will contribute to better health - thank bicyclists” and “Bikes are beautiful, cyclists is also”. The removal of the “Walk with bike” signs (that is used during construction) is important because the sign only shows that the bicyclists are not prioritized with a temporary solution. People have expressed that they like bicycle counting stations because they can se that they are not alone and it increase awareness.

An important service involves information about how to bicycle in the city (Trafikkontoret Göteborgs Stad, 2013). Additional services must also be supported: First is a map of the bicycle network that can be easily accessed from a smartphone/computer. Additionally, people want to be able to report problems and come with suggestions for improvements. However, the application must give confirmation if the reported have been fixed (Trafikkontoret Göteborgs Stad, 2013). Bicyclists have said that the municipality could make it more rewarding to write emails to the municipality about problems(Uppsala Kommun, 2012). Secondly, the service can provide information about bike repair shops, equipment stores and other relevant bicycle information and forums. Statistics, news and politicians views about bicycling are also requested.

The bicycling society have pointed out that there is a lack of knowledge about the traffic rules. An example is that people have problems with the yield rule and other traffic rules (NA, 2012). People have suggested clearer traffic rules at crossovers and other situations with additional priority in traffic (Trafikkontoret Göteborgs Stad, 2013). Information about traffic rules can by sending flyers to current residents and new inhabitants in the city, displayed in local newspapers and on billboards. Furthermore, traffic rules education and behaviour can be taught to school children and university students (Uppsala Kommun, 2012).

A few bicyclists break the law and behave dangerously. People do overtaking on the wrong side, drive in the left lane, drive in wrong direction in roundabouts and don't respect the right hand rule etc. Fines should be given to those who break the traffic rules. Furthermore, problems with illegal parking, blockage and uncoupled dogs have been brought to attention. As a consequence have a police presence been asked for to prevent the issues that is described above. In addition, can a ban on mopeds on the bike path be added (Trafikkontoret Göteborgs Stad, 2013).

The bicycling community wants to increase the signing along one-way road to get a quick understanding if they are one-way streets (Trafikkontoret Göteborgs Stad, 2013). In addition, the possibility for bicyclist to travel against traffic on one-way streets is requested because bicyclists are vulnerability to detours (SCS, 2013). At some locations does not one-way make any sense and can therefore changes to one-way streets for cars only (Trafikkontoret Göteborgs Stad, 2013). However, the one-way road must have sufficient width to ensure traffic safety (SCS, 2013).

One of the fundamental needs of bicyclist is traffic safety. Single accident is the most common followed by collisions with motor vehicles and other bicyclists. However, even if the minority of accidents involves mopeds, pedestrians and trams are there stile people who get hurt and this need to change. The need for an easy understanding of the traffic rules is requested for both adults and children to improve traffic safety (Trafikverket, 2012a). Falling accidents affect all but senior citizens are especially vulnerable due to lack of strength (Spolander, 2007). Elderly has a problem when they star-stop to get on/off their bike at traffic lights. One in five elderly are injured in bike accident in connection with traffic lights and traffic junction. The need is for elderly to be able to stay in their seat throw-out the whole trip. Furthermore, falling accidents also occur due to the road surface as the main source of injuries. Better maintenance with more check-ups, regular sweeping and removal of dangerous materials is requested (Svenska Cykelsällskapet, 2000). The regular sweepings are intended to remove gravel, glass etc. that is a big issue for safety (Göteborgs Stad, 2013).

Visibility concerns bicyclists and they want to limit the number of related accidents (Göteborg, 2012). Improvements to the visibility can be done by trimming trees and bushes as well as lower the risk of branches to be fixed in the wheels (Trafikverket, 2012a). Well-placed mirrors can partially solve the issue with visibility and vegetation but in not an ideal solution for the problem (SCS, 2013). Furthermore, root penetration, potholes and cracks in the road surface are issues that can also lead to injuries (Trafikverket, 2012a). Vegetation can also eat away the road surface and make the road narrower because grass, tree branches and bushes grows in on the bike path. Additionally, buildings can also cause visibility problems because at some locations are the cyclists unseen by vehicle drivers because they are hidden behind buildings and an mirror be of used in this situation (Trafikkontoret Göteborgs Stad, 2013).

During the hours or at places that is inadequate lit can single accidents occur. Bicyclists has proposed that all bicycle tunnels must be well lit, not only at night, but especially in bright sunlight when poorly lit tunnels may appear completely black (SCS, 2013). Bike lanes that are beside the main vehicle road can also be an issue due to the vehicle lights that blinds in the dark (Trafikkontoret Göteborgs Stad, 2013). Also, the painted centre markings are hidden during night-time and winter and the maintenance of the paint must be prioritized (Uppsala Kommun, 2012).

During winter is snow/ice a major issue and the first problem is snow blockages and snow makes it hard to ride the bike. People want more frequent removal of snow to cope with the problem (Trafikkontoret Göteborg, 2012e). Snow removal must get a higher priority in the traffic system (Uppsala Kommun, 2012) and the fresh snow cannot be more then 2-5 cm (SCS, 2013). Also, some bike paths can get higher priority to coordinate quicker snow removal and there must be shorter response times for snow removal (Uppsala Kommun, 2012). Furthermore, snow that is removed from the surface can’t be left as snow banks on the bike path according to bicyclists. People have also requested that the snow should be removed by 07:00 on the prioritized bike paths (Trafikkontoret Göteborgs Stad, 2013). Ice removal is one of the most important issues during winter, especially in hilly terrain (SCS, 2013). Also, water should be cleared on manhole covers, speed bumps, wells and water pools that freezes and becomes slippery (Trafikkontoret Göteborgs Stad, 2013). Information about prioritized bike lanes can be provided for people to understand were ice removal is prioritized. Heated bike lanes have also been requested to prevent snow/ice to form.

Between April and September is sand and gravel the largest reason for slip accidents when the surface and sand get dry (Trafikverket, 2012a). Hence, quick removal of sand/gravel is therefore requested (Trafikkontoret Göteborgs Stad, 2013). Additionally, the sand/gravel is unfortunately puncturing bicyclist’s tires and this must be looked into (Trafikkontoret Göteborgs Stad, 2013). However, sand/gravel have the advantage over salt because sand does not damage the bicycles. The ruff surface of gravel makes the trip uncomfortable and hurts the bike due to shaking. Glass fragments must be removed as soon as possible because it punctures the tires. Regular sweepings with shorter response time are therefore requested (Uppsala Kommun, 2012). Furthermore, slippery leafs on the road surface is also an issue and must be removed. Water bodies on the bike paths can also cause problems because it makes the bike path narrow (Trafikkontoret Göteborgs Stad, 2013).

Furthermore, bicyclists are sensitive to curbstones, cracks in road surface, potholes and sharp corners of any kind that hurts the bike wheel (Svenska Cykelsällskapet, 2000). Removal of all curbstones at entrances and exits from bike lanes is requested because curbstones causes speed reductions and falling accidents. A solution to the problem with curbstones is to have small ramps that help bicyclists (Trafikkontoret Göteborgs Stad, 2013). In addition, obstacles designed for cars is also affect bicyclist, therefore must future road obstacles that allows free passage for bicyclists be designed (SCS, 2013).

The overwhelming demand by bicyclist is the detachment from vehicle roads and sidewalks as the only viable long-term solution (Svenska Cykelsällskapet, 2000). Furthermore, another vision is vehicle free zones in city centers were unprotected travellers can move freely. However, the bicycling society has accepted that costs and space issues make them to shear space with pedestrian. Also, roller-skier, in-line skater, and various other athletes are acceptable. However, clear division signs or different road materials are requested between bicyclists and pedestrians (SCS, 2013).

Additionally, the Swedish bicycling community has concerns with bi-directional bike lanes due to the risk of frontal collision at frequently used routes. A frontal collision with two bicyclists at 25-30 km/h could lead to serous injury or be fatal. However, the community has recognized that bi-directional bike lanes are easy to construct, maintain and use. Bike paths must therefore be designed for four cyclists in width and fescue space for overtaking. Also, the di-directional lanes shall be divided with a clear centre mark that is clearly painted, stone-marked or equivalent designed (SCS, 2013).

In addition, pedestrians can be an issue due to shared space, especially at bus stops (SCS, 2013). Therefore should decoupling of pedestrian/cycling paths as bus stops be done as frequent as possible. Otherwise should the bike lane always stretch behind the bus stop due to conflicts between bicyclist and buss passengers. Also, commercial pillars are blocking the visibility that can cause a potential collision (Uppsala Kommun, 2012). Issues with bike lane between the main road and the bus stop must be looked into and dealt with.

Intersections between vehicle roads and bike paths are a major source of conflict between travellers. A dangerous situation is when a heavy vehicle turns right over a bike lane. The danger with this is the lack of sight for the vehicle driver and the momentum that the truck has when it turns (Trafikverket, 2012a). Furthermore, if bi-directional bike path is constructed beside a frequently used read should a buffer zone or road barrier be constructed (SCS, 2013). Priority at street light intersections is requested to improve their travel time for bicyclists (Svenska Cykelsällskapet, 2000). Additionally, detector can be installed were a critical mass of bicyclist travel and multiple traffic lights could communicate to ensure free passage. Signals without button pushing are asked for to avoid losing speed before the intersection (SCS, 2013). People want a support railing beside the push button so they can stay in their seat during the trip. Bike travellers have expressed that, at several locations, the traffic lights is confusing and not adequate. Therefore have people requested bike specific traffic lights that are easy to understand (Uppsala Kommun, 2012). Some traffic lights are positioned in a way that the front part of the bike is in contact with the main road when cyclist pushes the traffic light button. Also, bicyclists want a cycling box in front of cars to get a head start at intersections. The biking community have expressed that yield signs can be installed were bicyclists have priority at intersections (Trafikkontoret Göteborgs Stad, 2013). The Swedish cycling community has also requested a colour marking at intersections/passages in the asphalt and special road signs (Svenska Cykelsällskapet, 2000). The paint should be a national/municipal standard that is clearly distinguished from the asphalt (Trafikkontoret Göteborgs Stad, 2013). Light-blue, blue, green and yellow colours are preferred and the red colour should be minimized because it disappears into the pavement. In addition, the paint must have a ruff surface to ensure that no slipping accidents can occur. Furthermore, speed limits to 30 km/h at intersections is requested due to the high risk of injury. In addition, speed bumps or a countdown clock at traffic light intersections can be helpful. Bike lanes that cross two lanes shall have a traffic island for safety. At some intersections must the cars drive up on the bike path to get a better vision of the intersection, but then they block the bike path and it can be a source of collision.

Collisions with infrastructure are an additional problem on the bike network and therefore have people requested a removal of all obstacles on the bike lanes (Svenska Cykelsällskapet, 2000). There are issues with crash barrier because bicyclists collide with them and get tossed into the main vehicle traffic (Trafikkontoret Göteborgs Stad, 2013). People have therefore asked for an improved physical barrier between the cars and unprotected cyclists to shield them from danger. Also, at bridges can crash barriers don't protect people if strong winds occur and a fence design is therefore wanted. Furthermore, people's bike-wheels get stuck in tram-tracks that lead to falling accidents or/and make a flat tire (SCS, 2013). Consequently must the local traffic offices, in cities with a public tram network, keep bicyclist and tram-tracks in mind when designing new or current bike lanes (Trafikkontoret Göteborgs Stad, 2013).

Every traveller is interested about the time it takes go get to the intended destination. By comparing the amount of time it takes from point A to point B with bike and other means of transport, you will find that the critical time is between 15 and 30 minutes. If the trip takes longer will the person not bicycle to their destination. The time factor is of first priority, but some cyclist have expressed that commuting over five kilometres can be an issue (Trafikkontoret Göteborg, 2012b).

Obstacles on the road increase the travel time, therefore have people expressed concerns with illegal parking's, concrete blocks, booms, restaurant tables, street work, parking of machinery and temporary barriers etc. (Trafikkontoret Göteborgs Stad, 2013). If roadblocks occur due to construction shall a good alternative route be provided with a clear 'alternative-route' sign (SCS, 2013). In addition, the bike road should be open as long as possible during road construction and shall be finished as soon as possible (Trafikkontoret Göteborgs Stad, 2013). Also, the construction workers shall be more educated to be able to make the road surface smoother. The bicycling community has also some issues with permanent barriers that are designed to prevent unwanted traffic. Unfortunately are these barriers a problem for bicyclists too. Also, there is no warning before these obstacles and can therefore cause danger during the dark hours.

People have pledged concerns with the lack of bike lanes and a non-connected bike network without dead ends (Göteborg, 2012). Hence, bicyclists are therefore referred to the main car road or pedestrian sidewalk. If dead ends occur shall a road sign with a suggested alternative route be implemented at that destination. Furthermore, without an all connected network is more road signs for easier navigation demanded (Göteborgs Stad, 2013). In addition, the street signs can show distance to local nodes or sights. Bicyclists have requested street colours for different bike paths along with street names (Svenska Cykelsällskapet, 2000). Also, bike travellers have uttered a desire for 'express lanes' to make the trip time shorter (Göteborg, 2012).

Combination between public transport and bicycling is a major topic for people. People want to bring their bike on trams, trains, busses, fairies and subways (Trafikkontoret Göteborg, 2012e). Furthermore, it should be free to bring the bike in public trains (Trafikkontoret Göteborgs Stad, 2013). Also, bike racks on busses and public transport have been requested. By constructing public transport vehicles to have flexible storage areas on board, which can be used for multiple functions, can this solve this issue (Svenska Cykelsällskapet, 2000). Bicyclists understand that the bike cannot always be brought on the public transport during peak hours but bikes should be allowed to bring during off-peak hours.

If the bicycle cannot be brought onto the public transport are large parking spaces at key nodes requested (SCS, 2013). First, there is lack of parking space at various locations and this leads to overcrowding that damages the bikes and limits the parking ability (Uppsala Kommun, 2012). With the limited parking space is abandoned bikes and illegal parking an issue. Furthermore, people have requested integrated locking system, bike racks and the ability to lock their bike trailers (Trafikkontoret Göteborgs

Stad, 2013). In addition, guarded parking spaces and/or parking racks with lights can reduce the risk of theft (Svenska Cykelsällskapet, 2000). Also, current bike racks can be ill oriented that makes it hard to lock the bike and this is an issue that must be looked into. The bicycling community has requested more bike racks at the city centre, schools, universities and workplaces to keep up with the increasing demand. Secondly is a multi-storey parking house requested that can support high demand with additional services (Uppsala Kommun, 2012). The parking complexes can be located at larger nodes. According the bicyclists the building can protect their expensive bikes and trailers from weather and theft. Additionally, these larger parking spaces could solve the issues with long-term parking (Trafikkontoret Göteborgs Stad, 2013). The services that can be provided are: the ability to charge e-bikes, borrow a bike, pump station, tools, lockers for bike-cloths and helmet and dressing rooms with additional showers.

Bicyclist have expressed that their bikes can get broken during the trip and therefore are easy access to a pump stations asked for (NA, 2012). Additionally, pumps should be located within 500 meters of each other and they should fit every kind of bicycle (Trafikkontoret Göteborgs Stad, 2013). In addition, there could be additional repair tools at the pump stations (Trafikkontoret Göteborg, 2012e). When people don’t have access to a bicycle doe they want a bike to be provided for them and that problem could be solved with a bicycle sharing system (Trafikkontoret Göteborg, 2012e). A suggestion is to install stations outside the congestion fee tools and in the suburbs (Trafikkontoret Göteborgs Stad, 2013). There should be different kind of bikes to rent for different situations; an example is cargo-bikes, to be able to bring kids and cargo. People have also requested a leasing system to be able to rent electric bicycles.

Bicyclists sometimes need to go to multiple destinations for errands along the way as grocery shopping or leave the kids to school (Trafikkontoret Göteborg, 2012b). People have therefore expressed that they must use another mean of transport be able to do the tasks and toddlers and small children are a limiting factor. The car is essential to make their schedule fit during the week (Trafikkontoret Göteborg, 2012b). However, only the most committed bicyclist expressed an unwillingness to use a car.

The general demand from a Cycling-Route-Application is to get directions to a new destination or an old destination in a new way (CyCity, 2012). People also want to know how long time it takes and the distance between two locations. Furthermore, the application must be simple to use with a good UI[7], accurate address search, provide a reasonable route with less car traffic and available on their smartphone. It is also important to have route suggestions that are flexible if the cyclist rides of the suggested route. The demands on the proposed route is that it must be fast with few curves and hills with dynamic route options due to congestion or obstacles. The bicyclists also expressed interest in bike-routes that is easy for children to use or that you can combine cycling with public transport. Studies show that the speed of the route is most important for the age groups under 45 years compare to the older group that values safety. Therefore have one suggestion been to have multiple routes with different colours that represents the fastest and the safest (CyCity, 2012).

On the countryside can the bike network be improved by constructing more small size bicycle roads within and between municipalities along national roads (Svenska Cykelsällskapet, 2000). However, the bike lanes shall not be in connection with the main vehicle road. Old and unused railway tracks can be reconstructed to bike lanes

[7] User interface

between regions. Also, construct more bicycle friendly rest stops at the countryside with additional name and protection against whether.

Additional improvements to the bike lanes could be to build shortcuts in the city were the bicycle could have an advantage over cars and public transport (Uppsala Kommun, 2012). The cycling community have also expressed that they would like to get the same amount of physical space as the vehicle traffic. An example of this is that the curbside parking spaces can be removed for cars and be given to the bike network. Another proposal is to make the four lane vehicle roads to a 2+1 road with a new bike lane for bidirectional paths (Trafikkontoret Göteborgs Stad, 2013). When a bike lane is constructed beside a pedestrian sidewalk and the main road should there be a level difference to easy see the difference between the road types. Also, if bicyclists and vehicle traffic share space should the speed be limited to the speed of the bicyclists. At some locations crosses the bike path the main road in a $ formation and that is very unnecessary according to the bicycling community. The bicycling community has also requested more bike lanes that cross natural borders, for example bridges and farriers. People have also asked for better connections between different regions.

Routes should not be constructed in a way that the bicyclists are forced to switch sides on the main road. Also, right-turn against ‘red light’ is also a wish or an added lane in the same situation (Svenska Cykelsällskapet, 2000).

People have also expressed other smaller improvements and that is to be able to participate in checking the quality of the road network (Trafikkontoret Göteborgs Stad, 2013). Also, to construct ‘super’ bike lanes were bicyclists could move quickly thru the urban center and have priority over motorists (Uppsala Kommun, 2012).

There have been some requests to increase the user-friendliness of the network for kids and seniors so they can move freely with more 30 km/h signs and vehicle free zones in the city. Also, by constructing more bicycle lanes to schools and make the area to a vehicle free zone (Uppsala Kommun, 2012).

According to bicyclist is the ideal bike lane often described as countryside experience compared to an urban area. Bicyclist want a relaxed near earth experience with nature, fresh air, no stops and open areas as can be seen on bike lanes in parks. People have therefore expressed issues with pollution and noise form vehicle traffic during their trip because the bike lanes is located beside the main car road. Pollution is a health hazard and it affects people with asthma and children most according to bicyclists. Bike-trailers for kids are in the height of vehicle exhaust pipes and is therefore in direct line with children’s respiratory systems and this is a major concern for bicycling parents.

The weather is a major factor for almost every bicyclist where rain and snow plays the major obstacle for comfort. The amount of rain is important for people to determent if they will bike or not. The same goes for the snow, but there are some who uses studded-tires on their bikes to get to work (Trafikkontoret Göteborg, 2012b). People have therefore requested more weather protective solutions to protect travellers from rain, wind and cold whether (Trafikkontoret Göteborgs Stad, 2013).

5 INTELLIGENT TRANSPORT SYSTEMS

To increase the readers navigation and understanding of the different intelligent transport systems has the following headings been selected:

Purpose

The function of the ITS system is portrayed here.

Application description

This part will explain the intelligent systems design as well as power source and communications equipment. The manager of the system and its intended location in the traffic system will also be explained.

In the end of the chapter will the following 'quick read' box be inserted (see table 1) for the reader to be able to quickly get en overview of the described ITS system.

Purpose	-	**Location**	-
Power source	-	**Operator**	-
Communication	-	**Current usage**	-

Table 1: Quick read box of the ITS system

In the succeeding chapters, is based on the following questions:

- What is the purpose and what need is the system addressing?
- What type of system is it and how is it designed?
- Were in the traffic system is the system used?
- What communication capability has the system?
- What information does the system provide?
- Who can take part of the gathered information?
- Were does the system get power?
- Are there any environmental effects?
- Where is the system currently used?
- Are there any ethical dilemmas with this system?
- Who will manage and operate the system?

The succeeding chapters have been divided into bicycle-based systems, managing traffic, monitoring traffic and providing information for increased understanding. These divisions have been done after analysing and link of the individual systems (see appendix D). In addition, an outlook on future systems in development has been looked at in chapter 'systems on the verge'. The following intelligent systems are both part of the infrastructure and non-part of the infrastructure.

Bicycle-based improvements

- ❖ Airbag helmet for cyclists
- ❖ Bicycle breaking light
- ❖ Bicycle sharing system
- ❖ Electrical assisted bicycles
- ❖ Guarded bicycling parking
- ❖ LED lights on wheel spokes
- ❖ Protected bicycle parking
- ❖ RFID-chip-tag

Managing traffic

- ❖ Enhanced Warning at Crosswalks
- ❖ Green Wave
- ❖ Intelligent road studs
- ❖ Intersection Warning system
- ❖ LED-lane road studs for right turn
- ❖ Motion detector system
- ❖ Pre-green traffic light
- ❖ Rain-Sensitive traffic light
- ❖ Right-turn-warning system
- ❖ Solar road studs
- ❖ Traffic light countdown

Monitoring traffic

- ❖ Bicycle counting pillar
- ❖ Cycle counting station
- ❖ Pyroelectric counting sensor

Providing information

- ❖ Web and APP based systems

Systems on the Verge

- ❖ Speed vest
- ❖ OpenBike system
- ❖ CopenhagenWheel

5.1 Bicycle-based systems

5.1.1 Airbag helmet

Purpose

The purpose with this product is to increase the traffic safety by giving people that don’t use bicycle helmets an alternative.

Application description

There is lot of falling accidents today and lot of adult doesn’t use helmets. This system is design to protect the head when a cyclist falls. The airbag is designed as a collar that is placed around the cyclist’s neck (Hövding, 2013). Inside the collar is a folded airbag that only can be seen when it releases when an accident occurs (see figure 11). The airbag is designed to work for all people with all accessories/hairstyles. Furthermore, accelerometers and gyroscope sensors inside the collar can detect an accident as abnormal movement. Then a sensor has been triggered are a signal sent to a gas inflator that inflate the airbag in 0.1 seconds. The collar can distinguish normal- from abnormal movement by an algorithm that is based on known accident patterns. The airbag fibers are design to withstand the forces of any accident and the airbag can withstand a number of impacts during the same accident. The airbag will start to deflate when the accident has come to a stop. The collar is also equipped with a “black box” that records the last 10 seconds of the movement by the cyclist. The reason for this is that the company wants to examine the incident and improves their product. Furthermore, there is no communication device built in other then the “black box” storage that can de analysed. This is a consumer electronics device; therefore is the personal cyclist in-charge to managing the system. Moreover, the airbag helmet is intended to be used in all traffic situations. Rechargeable batteries power the system.

Figure 11: Picture of a before and after the airbag is inflated (STMicroelectronics, 2012)

Purpose	Safety	**Location**	Mobile
Power source	Battery	**Operator**	Private
Communication	-	**Current usage**	-

5.1.2 Bicycle braking light

Purpose

This system is designed to prevent rear collisions by give a signalling that the bike is reaccelerating to the person behind the bicycle (Lucidbrake, 2013).

Application description

This intelligent breaking light system can be mounted on a general bike design (under the seat) as can be seen in figure 12. The taillight is intended to be used on main road as well as on bike paths. The device does not require any additional installation and one of the major advantages with this system is that the bicycle doesn’t need to be modified or customized in any way. Compared with other systems can this intelligent taillight adapt to the traffic situation. The LED lights flashes until the bike comes to a standstill. The rear light under the bicycle seat becomes brighter when the bicyclist breaks compare to when he/she slows down. Additionally, one situation where the system can be used is when a group of bicyclists is cycling and one break. The system can then alert people behind the bicyclist and a possible accident is therefore prevented. A similar situation is when the bicyclist cycle on the main road together with motorized vehicle traffic. In addition, it is therefore easy for the motor vehicle to get a direct indication when the bicyclist break and can therefore address the situation in safer way. The system does not have any communication other then the increased message that the bike breaks. The breaking light is designed to gets electricity from batteries. The intelligent transport system is a private product that is managed by the bicyclist (Lucidbrake, 2013).

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Figure 12: Picture of the bicycle breaking light system (Lucidbrake, 2013)

Purpose	Safety	**Location**	Mobil
Power source	Batteries	**Operator**	Private
Communication	-	**Current usage**	-

5.1.3 Bicycle sharing system

Purpose

The ide with this system is to provide people with easy access to a bike if they need to move fast around the urban environment.

Application description

The system is constructed in a way that bicyclists can rent a bike from one station and returns it at another station at the destination (Göteborgs Stad, 2013a). A typical bicycle sharing station is illustrated in figure 13. The bikes can be equipped with tracking devices and can automatically collect data about how the bikes are used, travel times, frequency, distance travelled, etc. (Jensen, 2008). This information can be used as foundation to improve the bike-lane network by the local traffic office. A municipality or a company can manage the stations and they are connected to the local power-grid. There are different types of bikes that can be rented that are suitable for most situations. There are some bikes that have extra storage capacity as well as traditional bikes. The stations are mostly located near public transport, housing areas, commercial areas but also close to workplaces and recreation zones.

Figure 13: Illustration of a Bicycle sharing system (Crispgreen, 2011)

Purpose	Accessibility	**Location**	Stationary
Power source	Power grid	**Operator**	Private/Government
Communication	-	**Current usage**	Global

5.1.4 Electrical assisted bicycles

Purpose

The problem that this technology addresses is the extra power that the bicyclist needs in times with hilly terrain, strong wind, long distance or exhaustion.

Application description

The bike is generally designed as an ordinary bike with an extra 2-8 kg battery as can be seen in figure 14 (CyCity, 2013). The battery works best if it's protected from cold temperatures (below 5°C) and typically needs to be charged after 30-70 km. The mean speed increases with about 40% and the electric bikes are designed to be uses on bike lanes or the main road. The bicycle is equipped with sensors that can detect when the cyclists need assistance (Batbike, 2013). Also, some bicycles have a control panel where the level of assistance can be changed. An electric assisted bike can help the bicycle up to 25 km/h in strong winds or hilly terrain. The battery can be fully re-charged within 4-6 hours. The hybrid bikes can also have an integrated intelligent pedal assistance and a regenerative braking system (Sanyo, 2013). The intelligent pedal assistance will not jolt the cyclist and it will feel natural to ride with the electric motor assistance. The regenerative braking system will recharge the battery wile pedalling, breaking or going down hill**.** The electrical assisted bicycles are an environmentally friendly mode of transport that is pollution free. The battery has a power of around 250 watt. This is a mobile product that can be used at any location in the traffic system. The electrical assisted bicycles is intended to be private property and there for are the private person at hand the manager of the ITS system.

Figure 14: Sanyo Eneloop electric bike (Sanyo, 2012)

Purpose	Range extender	**Location**	Mobile
Power source	Battery	**Operator**	Private
Communication	-	**Current usage**	Global

5.1.5 Guarded bicycle parking

Purpose

The purpose is to prevent bike theft by providing a secure parking space.

Application description

This system is a supervised parking space where security cameras are used to protect the bicycles from thieves (Fietsberaad, 2006). First is a parking house constructed were the bicycles can be parked. The idea with this system is to have one or more supervisors that manages the parking area and operated the multiple security cameras. The video images is recorded and stored if police action is needed. The cameras are installed in the ceiling to get the best overview and they can also detect movement. Furthermore, for extra protection is an automated controlled access system installed. Only bicyclists with a special pass have access to the guarded parking area as can be seen in figure 15. To increase the efficiency of the parking area is multi-level bike racks used where a telescopic slide-out grooves with gas springs is used and this makes the lifting of the bike less of an effort as can be seen in figure 16. The system gets electricity from the power grid. The parking building is generally located close to the major transit hubs. A private company or the local traffic office can manage the guarded parking system.

Figure 16: Picture of the automated control access system (Fietsberaad, 2006)

Figure 15: Picture of the multiple storage racks (Fietsberaad, 2006)

Purpose	Prevent thief	**Location**	Any location
Power source	Power Grid	**Operator**	Private/Government
Communication	-	**Resembling**	Zutphen, NL

5.1.6 LED lights on wheel spokes

Purpose

To increase the visibility of cyclist during the dark hours can LED lights on the cycle spokes be used (see Figure 17).

Application description

The increased visibility of the cyclist in the night will increase the traffic safety of the bicyclists (Hokey Spokes, 2012). The LED lights are designed for night-time travellers, bike couriers, bicycling police units and others to increase their visibility. The system is installed on the spokes (with a wheel diameter of 60 cm or greater) of the bicycle and it can be programmed for different colour light effects and be activated by movement of the bike. Furthermore, the electric spoke gets power from AA batteries per LED. There is no communication instrument and can therefore not collect or transmit data. The system is designed to be waterproof to sustain damage from rainy weather. The individual bicyclist will manage the intelligent transport system for his or her own safety. The LED lights are places on the individual's bicycle and are therefore a mobile device.

Figure 17: LED lights on bicycle spokes (Flashwear, 2013)

Purpose	Safety	**Location**	Mobile
Power source	Batteries	**Operator**	Private
Communication	-	**Current usage**	-

5.1.7 Protected bicycle parking

Purpose

This bicycle locking system is designed to protect bikes from theft by locking them into steel boxes that can only be locked and unlocked by the user.

Application description

The protected bicycling parking is designed as a secure on-demand parking system for bicycles (Bikelink, 2013). The system can be used, as an individual parking space or a group parking space were a number of bicycles could be stored. Furthermore, by enabling a safe parking space close to transit stations can this system make it easier for people to use other mobility alternatives as part of their trip as can be seen in figure 18.

Figure 18: Illustration of a protected bicycle parking system (Bikelink, 2013)

Figure 19: A close-up picture of the locking boxes (Bikelink, 2013)

People get access to the locks by purchase a card filled with points that can be used to unlock the parking spaces. A close-up picture of the bicycle locking system can be seen in figure 19. The card is inserted into the reader and the bicyclist uses buttons to ad the needed parking time. When the time is selected and the card is removed will the door open and the bike can be inserted into the lock. Furthermore, when the cyclist comes back is it only to insert the card and the door will open. The protected bicycling parking system gets electricity from AC power or from batteries and it works with and without a network. The system can be placed at any location but in connection with large public transport hubs is a common location. A private and government body can manage the protected parking facilities.

Purpose	Prevent thief	**Location**	Any location
Power source	Batteries	**Operator**	Private/Government
Communication	-	**Current usage**	San Francisco, US

5.1.8 RFID-Chip-Tag

Purpose

The purpose of this chip is to prevent bike theft as well as give incentives to new bicyclists.

Application description

The RFID-chip is a radio frequency identification device that can provide the information about the owner by taping the bike with a RFID scanner (Copenhagenize, 2009). The chip has a unique serial number and it is mounted inside the bicycle or on the bike wheel (see figure 20) and registers to the owner via a company that manages the system (Immobilise, 2013). The chips are a low cost solution to prevent bicycle thefts (SBR, 2013). The RFID-chip can also be a part of a reward system were a RFID tag is places on the front-wheel on the bicyclist personal bike and the person gets points by "check in" at different stations around the city (see figure 21) (Cykelskore, 2013). This is a way of the municipality/city to give an incentive for their citizens to start cycle to their destination. The stations get power from the power grid. The local traffic office can gather the information about the bicycles movement and this can be used as a bas for future development of the bike network. Furthermore, the Police can also use this system to locate stolen bicycles. The RFID-chips are mobile components inside or on the bicycle and the station can be stationed at any location. The system can be managed by the city, municipality or by a private company.

Figure 20: Example of an RFID-chip enabled bicycle (ECF, 2013)

Figure 21: Picture of a Check-in-station for the RFID-chip system (ECF, 2013).

Purpose	Thief/Incentive	**Location**	Mobile/Stationary
Power source	Power grid	**Operator**	Government
Communication	-	**Current usage**	Fredricia, DK

5.2 Managing traffic

5.2.1 Enhanced Warning at Crosswalks (EWaC)

Purpose

The intention with this system is to provide a warning to oncoming traffic that a cyclist is about to cross the road.

Application description

Figure 22: Picture of an EWaC sign (Amparosolutions, 2013)

The idea with this ITS system is to give vehicle traffic a warning of a passage, on roads that have the speed limit 50 km/h or more, so the vehicles can address the situation safely (Baghdarusefi, 2012). The system is design with a warning triangle, with or without text, with one or multiple LED lights that flashes towards the cars when a cyclist is detected as can be seen in figure 22. The detection of a cyclist is done via a microwave sensor, radar or an infra red (IR) detector that is placed on a post nearby. The IR-detector is designed to detect if it's one or more oncoming cyclist. There are no limits on how many detectors that can be connected to the warning signs. There area multiple enhanced information systems at bike/pedestrian crossings available on the Swedish market today. There are different designs of this system today but the main designs are called a *VMS-sign, SeeMe system, Safe X system* and *Luno*. The system is batteries powered and the batteries have a life length of at least five years. The EWaC system also can be equipped with solar cells and this will increase the electricity supply of the ITS system (Amparosolutions, 2013). The system has no communication equipment and can therefore not collect or transmit any data. The enhanced warning system is placed at intersections between bicyclist and the main motor vehicle road. The local traffic office that has installed this system will also manage the EWaC system.

Purpose	Traffic Safety	**Location**	Passages
Power source	Battery	**Operator**	Government/Private
Communication	-	**Current usage**	Stenungsund, SE

5.2.2 Green Wave

Purpose

The idea with this system is to give bicyclist priority in the traffic system by providing the cyclists with a flow of green light to decrees travel time (see figure 23).

Application description

Figure 23: Illustration of the Green Wave in Amsterdam (Fietsberaad, 2013)

Green Wave is a term for a traffic management technique where a coordinated traffic light system can increase the traffic flow for the bicyclist thru the urban centers (Greenwaveevents, 2012). In addition, by programming the traffic lights to give priority to the bicyclist will the travel time decrease for bicyclist and this can be an incentive for more people to bike to their destination. There is a time zone were the bicyclist have green light thru the whole system. An example is that if the cyclist have 60 seconds of green light, he/she want to pass through the intersection at the 30 second mark because the cyclist have therefore a spectrum of speed to be able to pass thru the system (Yairharel, 2012). The average speed for a bicyclist is around 15-20 km/h. Green Wave is integrated into the existing traffic lights at intersections and is has therefore the same power source. The system itself does not collect any information but the traffic lights displays the information on who has the green light. The environmental effects are that the system gives priority towards the bicyclist; hence, the vehicle traffic will be standing in traffic light more often. However, the Green Wave system can give an incentive to people to start using their bicycles. The Green Wave system for bicyclists has today been implemented in the Dutch city of Amsterdam. The system is integrated into several traffic lights at different intersections to create a route with green light for the bicyclists. The local road office at the intended municipality will manage the Green Wave system.

Purpose	Travel time	**Location**	Intersection
Power source	Power grid	**Operator**	Government
Communication	-	**Current usage**	Amsterdam, NL

5.2.3 Intelligent Road Studs

Purpose

This intelligent system is designed to prevent collisions by light up the bike-lane with LED lights or along the sides of the path (Walkinginfo, 2013).

Application description

One of the main uses of this system is to raise awareness in real time at pedestrian crossings and bicycle paths (Amparo, 2013c). The lights provides a warning for vehicle traffic that a bicycle is crossing the road and the road studs also lead the bicyclist to the correct path in the dark (see figure 24). The system is designed as a small cylinder that is placed in the pavement at the same level as the asphalt pavement. The road studs are visible up to 1000 meters and have been proven to work during winter in the Scandinavian climate. The intelligent road studs can be installed with a variety of colours for different purposes. Furthermore, the intelligent road studs can be used in a variety of different situations. An example of this is to give advanced guidance of different routes in areas such as industrial or port areas marked by different colour markings. Additionally, this system does not have any communications equipment and cannot gather any information about its surroundings. The system is usually placed in tunnels, intersections and road crossings, sharp curves and roads with inadequate or non-existent street lighting (Amparo, 2013c). The local traffic office at the municipality manages the intelligent road studs. Batteries power the intelligent road studs.

Figure 24: Illustration of the intelligent road studs at a crosswalk intersection (Amparo, 2013c)

Purpose	Safety	**Location**	Intersections
Power source	Battery	**Operator**	Government
Communication	-	**Current usage**	-

5.2.4 Intersection warning system

Purpose

This system is designed to increase the safety of cyclists at traffic lights by warning heavy vehicles that a cyclist is present (RFID journal, 2013).

Application description

There is a display mounted on a traffic light that can easily be seen by the car/truck/bus driver as can be seen in figure 25 (RFID journal, 2013). The ITS system is developed by a company called See-mi in Denmark and it is in use in Copenhagen and London. Furthermore, the system is designed with a RFID interrogator that is installed on the traffic light and a RFID reflector mounted on the bike. The bike will be detected when it enters within a 10-25 meter radius of the traffic light. When the traffic light has detected the bicyclist it will send a signal the display that gives the vehicle driver the information. The position of the display is placed strategically in the line of sight of the driver. Also, the display flashes the message to the driver to make it easy for him/her to get the message. Resembling systems are see-Mi warning system and the right-turn warning systems. This particular technique is installed onto a traffic light at potential dangerous intersections. The local traffic office in the municipality manages this system.

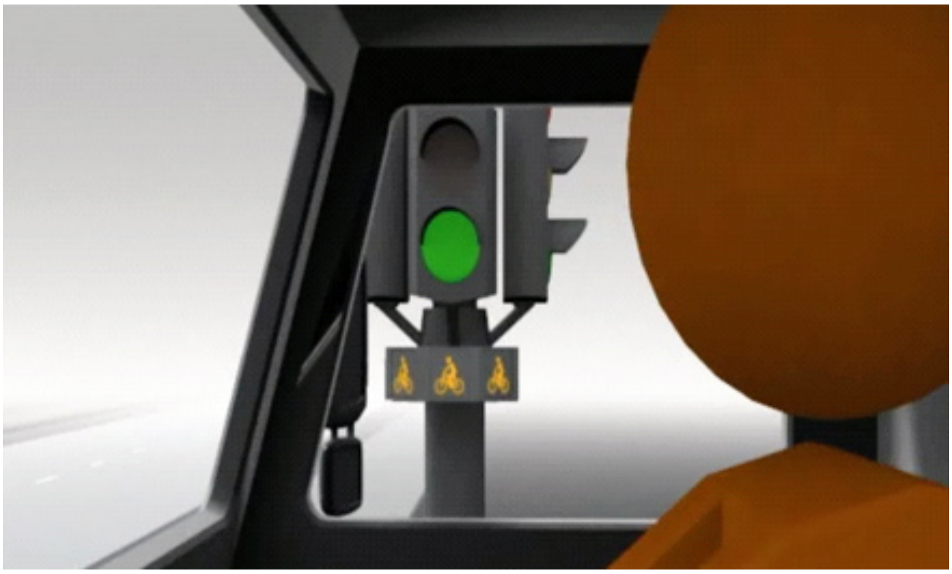

Figure 25: Illustration of the See-me warning system (ThinkMagic, 2013)

Purpose	Safety	**Location**	Intersection
Power source	Grid based	**Operator**	Government
Communication	RFID	**Current usage**	Copenhagen, DK

5.2.5 LED-lane road studs for right turn

Purpose

To increase the traffic safety at T- or Cross-intersections by lighting up LED lights to alert vehicle traffic of crossing bicyclists (see figure 26).

Application description

This innovation is designed to decrease the number of accidents with vehicle and bicyclists at right turn intersections (Gustafsson, 2011). The technology is designed as 13 LED lights that lit up when a bicyclists is close to the intersection. The sensor is places about 25 meters before the intersection. When the intelligent system has sensed a bike traveller will the system activate the 13 LED light and blind at the side of the road. The system is designed to only activate the LED light when the bicyclist have green light at the same time as the vehicle traffic and is therefore not active when the bicyclist has red light. The road studs are placed between the main road and the bike path in the asphalt. In addition, the lights are easy to see during day- and night-time. Due to the fact the lights blink when a cyclist is present, will affect the driver to recognize the potential danger of the situation. Studies from Copenhagen have showed an up-to 50% decrease in traffic accidents at the intersections were the system has been installed. The system has no communication to a central server and data can therefor not be analysed. There are no clear environmental effects of ethical dilemmas with this type of system. The LED-lane road studs are currently implemented in Copenhagen, Denmark and are up for end revue during the spring of 2011. This system is installed at intersections were there is a risk for collisions between vehicle traffic and bike traffic. This system is under evaluation at the time but the road manager will operate it. Batteries power the system.

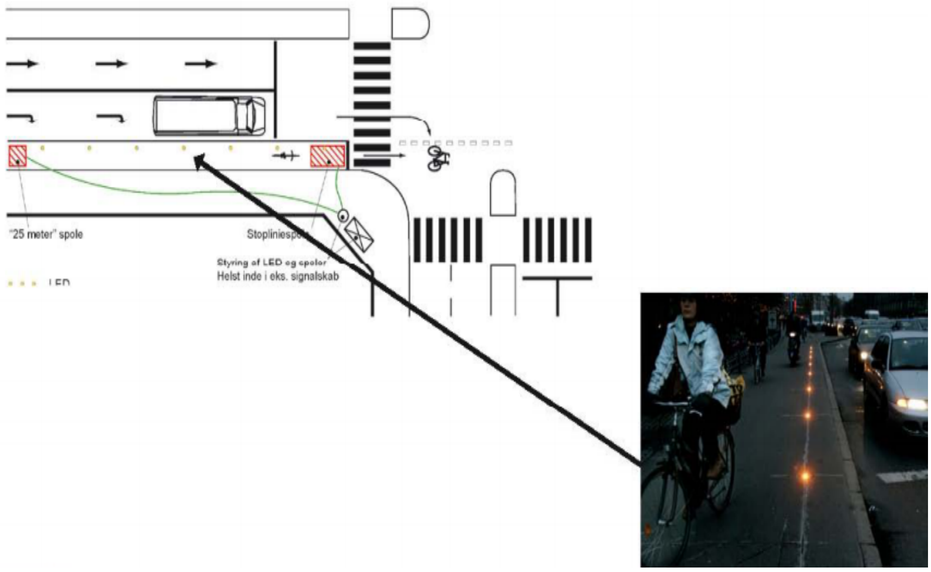

Figure 26: Illustration of the LED lights position for the mentioned traffic situation (Trafikverket, 2011b)

Purpose	Safety	**Location**	Intersection
Power source	Battery	**Operator**	Government
Communication	-	**Current usage**	Copenhagen, DK

5.2.6 Motion detection systems

Purpose

The detector system has the purpose to increase the accessibility for bicyclists by automatically detect people wile standing at the curb or moving towards the road crossing area as can be seen in figure 27 and 28 (Walkinginfo, 2013a).

Application description

The infrared- and microwave detector systems operate in a same way with different technologies. Additionally, as the name indicates uses the system a wavelength in the far infrared and microwave part of the electromagnetic spectrum were it could sense the slightest changes in temperature. The system is designed to sensing the changes in thermal radiation caused by movement within the field of view.

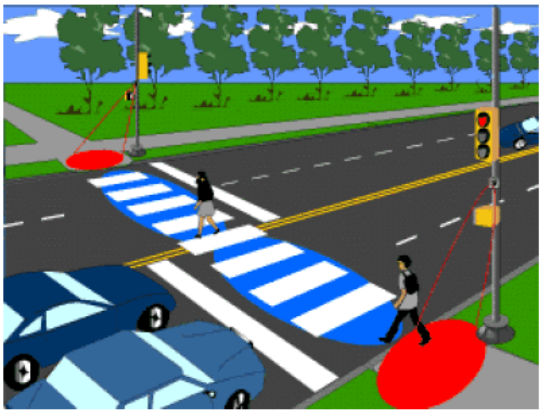

Figure 27: Illustration of the infrared detector system (FHWA, 2013)

Hence, when a person enters the area will he/she change the temperature, which the instrument will detect. If the system detects a bicyclist will the system extend the clearance interval and provide more time to cross the road (PedSmart, 2013). When the system has detected a cyclist will it automatically respond with a standard traffic light button push and therefore decrease the waiting time for the cyclist. The motion detectors are places at least 3.5 meter above the street and it emits electromagnetic energy that is being reflected by the bicyclists (Walkinginfo, 2013a). The system can be a supplement or a replacement to the standard pushbutton therefore is the intelligent transport system is only an additional feature to the current traffic light. The motion sensors are installed on traffic light at intersections between the main road and the cycling lane. There is no communications equipment that can transmit data to a central hub. This particular ITS system will be managed be the road authorities or by a private company that specialize in the field.

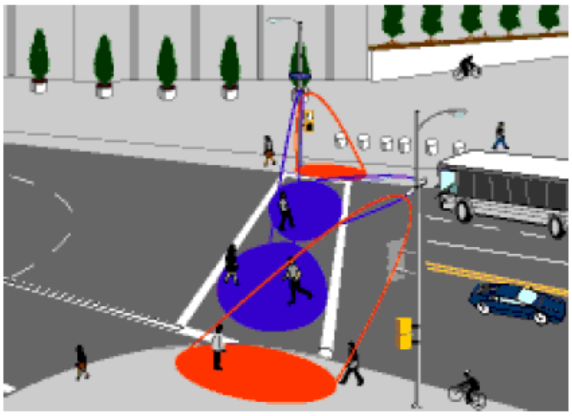

Figure 28: Illustration of the microwave detector system (FHWA, 2013)

Purpose	Traffic flow	**Location**	Intersection
Power source	Power Grid	**Operator**	Government
Communication	-	**Current usage**	-

5.2.7 Pre-green traffic light

Purpose

This system is has the purpose to increase the traffic safety for bicyclist by giving them a head start at traffic light intersections.

Application description

The pre-green system is designed to be implemented on existing traffic lights at intersections. The best way of implement this is to have a ‘cycling box’ were bicyclist could be in front of the vehicle traffic (Gustafsson, 2011). The idea is to give the bicyclist about 10-15 seconds head start to prevent collisions with vehicles when they do a right turn at the intersection. The vehicle capacity at the intersection could be affected by this change but the gain in traffic safety for bicyclists is something to keep in mind. The system has no communication to a central hub but it is communication to the travellers that the bicyclists have a head start for a few seconds. The pre-green application cannot gather any information and can therefore just transmit the installed function. Furthermore, the system is installed on existing traffic lights that is connected to the power grid and is therefore its source of electricity. There is no clear environmental effects connected to the system other then the vehicle traffic pollution that is connected to the increased waiting time. The pre-green traffic light system is installed in existing traffic lights at intersections. The system is an add-on to existing traffic light signals and therefore is the provider of the traffic light the operator of the ITS system.

Purpose	Safety	**Location**	Intersections
Power source	Power grid	**Operator**	Government
Communication	-	**Current usage**	-

5.2.8 Rain-sensitive traffic light

Purpose

The rain-sensitive detecting system has the purpose to increase the green time and give priority to the bicyclist when it's raining to improve the traffic safety (Eltis, 2012).

Application description

Figure 29: Picture of the rain-sensitive device (Fietsberaad, 2012)

The system is designed as a horseshoe with optical rain sensors that emit infrared signals (see figure 29) (Eltis, 2012). Detection is registered when rain or snow interrupts the infrared sensor. The device is designed to get hot and can therefore detect snow when the snowfall melts. When the sensor has detected precipitation and detected a bicyclist thru a detector system or by the push button will the system send a signal to the traffic light to changes to green light and delays it (Fietsberaad, 2012). There are different models in the market today; first is an ITS system that detects rain/snow and secondly are a system that can detect up to four levels of precipitation and act accordingly. One disadvantage of the system is that is can not be installed on traffic lights that are part of a network due to interference with the traffic light chain. The ideal use of a rain sensor is at intersections with a high flow of bicyclists. The rain sensitive system is similar to the commercial available system for public busses (Fietsberaad, 2012). In addition, other vehicles in different directions that don't cause conflict will be benefited as well. However, if a bus and a bicycle in conflict will be detected at the same time, the bus will have priority. Additionally, the bicyclist cannot obtain extra green time if the maximum cycle time has been reached. The system does not have any other communication equipment and can therefore not collect any information. The system is to be installed on current traffic lights at intersection go give them this extra feature. The local traffic office will manage the rain-sensitive intelligent system. Batteries power the system.

Purpose	Traffic flow	**Location**	Intersections
Power source	Battery	**Operator**	Government
Communication	-	**Current usage**	-

5.2.9 Right-turn-warning system

Purpose

This system is designed to increase traffic safety by warning vehicle drivers in a right turn that a bicyclist is present.

Application description

This is a system that is mounted on a truck that can detect a person and make a sound signal if the truck is going to do a right turn (Lisa2Alert, 2013). The system turns on when the truck is moving slower then a certain speed; witch then the system warns the driver and bicyclist of the situation. At the same time as the system makes a sound signal will it also have flashing lights as indicators. The system is designed with a signal unit, a push button, and a connection unit as well as electronics boxes to connect the system with power. The driver uses the push button to deactivate the sound signal if that is needed. The drawback of this system is that the system does not detect bicyclists that are in front of the truck mirrors. The sense of responsibility can shift from the driver to the bicyclist. The sound of the signal can also be a disturbance in public areas.

Figure 30: Picture of the position of the rubber stripes used in Lexguard (Intertruck benelux, 2013)

An second alternative to protect cyclist when trucks, trailers, buses and delivery trucks turn right due to the blind spots (Intertruck benelux, 2013). The system is designed to work by mounting a rubber strip on the right hand side of the vehicle. The stripes are placed in the front of the truck and on the side as can be seen in figure 30. However, sensors inside the rubber stripes detect the cyclist and will an alarm in the cabin warn the driver. The system is also equipped with a GPS tracking system to automatically engage when the vehicle travel below 30 km/h to prevent the driver from getting unnecessary warnings. Furthermore, the stripes can detect a cyclist up till 1,25 meters and the system will give an more intense warning if a person comes 40 cm or closer. The intelligent system gets power from batteries.

Purpose	Safety	**Location**	Mobile
Power source	Battery	**Operator**	Private
Communication	Sound	**Current usage**	-

5.2.10 Solar road studs

Purpose

The road studs are intended to reduce fatal and non-fatal (Amparo, 2013d).

Application description

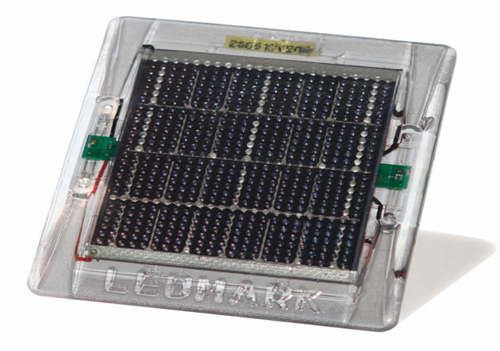

Figure 31: Pictures of solar road studs (Falco, 2013)

Figure 32: Illustration of the solar LED light in a poor lit environment during the dark hours (Falco, 2013)

The system is designed as a sturdy small cylinder with LED-lights that is placed in the pavement (se figure 31). The road studs uses sunlight to power them during the day and emitting light during the dark hours. The solar electrified road struts are self-sufficient and is therefore does not harm the environment or contribute to carbon dioxide pollution. There are no communications equipment inside the road studs and can therefore not gather information. The system is designed to operate during the whole year in the Nordic climate and can be used between -40 and +80 degrees Celsius. The light can be seen up to 900 meters. The batteries inside can be used for 240 hours on a single charge without power from the sun. The time to recharge from the sun is about 3 hours. There are many appliances for this system and some of them are to mark complex intersections, ramps or at dangerous curves and bumps. The system can also help to define the bike path during the dark hours and also increase the visibility when ordinary the lighting is not available because it is too expensive or when it simply not possible (see figure 32). The solar road studs can be installed with special glue that sticks to the asphalt (Falco, 2013). Furthermore, the LED lights can be used to warn the bicyclist from an icy surface that can cause a falling accident. The system can also withstand plowing machine and road salt that is used during winter. The system is usually placed in sharp curves or roads with inadequate or non-existent street lighting. The solar road studs are managed be the local traffic office.

Purpose	Safety	**Location**	In pavement
Power source	Solar cells	**Operator**	Government
Communication	-	**Current usage**	-

5.2.11 Traffic light countdown

Purpose

The purpose of this system is to have fewer red-light-crossings of the cyclist and therefore improve the safety (Mobycon, 2012).

Application description

This system goes into effect when a cyclist reaches a red traffic light then will the cyclist see the countdown timer (see figure 33) (Mobycon, 2012). The information that it provides is the relative waiting time for the cyclist until he/she get a green light. The system can be designed as a static or dynamic system that can detect a cyclist with sensors and address accordingly. This system is generally used in an intersection between car and cycling traffic. The system must be plugged in the power grid to function. The system does not have any central communication but does only enhance the information that is provided by the traffic light. The Traffic light countdown system gets power from the power grid. The countdown system is installed in an intersection between the motor vehicle road and the bike path. This ITS system will be managed by the municipality. The intelligent countdown system is currently used in the Dutch city of Amsterdam.

Figure 33: Part of a picture of a countdown traffic light for cyclist (flickr, 2006)

Purpose	Safety	**Location**	Intersections
Power source	Power grid	**Operator**	Government
Communication	-	**Current usage**	Amsterdam, NL

5.3 Monitoring traffic

5.3.1 Bicycle Counting Pillar

Purpose

The idea with this intelligent system is to count the number of bicyclists and broadcast the information back to the bicyclists on the spot (Amparo, 2013a).

Application description

The system is designed as a pillar at the side of the bike lane and it counts the number of cyclist and displays the information to the sounding public in real-time as can be seen in figure 34 (Amparo, 2013a). The pillar can be installed to count the number of bikes in a single direction or in both directions. By presenting the number of bicyclist per day/month/year could give an incentive to other people to start to use the bicycle instead of their car. Also, it can engage the community and keep the current bicyclist to use their bike. The Bicycle Counting Pillar uses inductive loops to detect and register the number of bicyclists (eco-compteur, 2013). Power comes from the local power grid and it communicates via a GPRS/3G Internet antenna (Amparo, 2013a). Furthermore, this system will get the operator (usually the local traffic offices at the municipality) an idea of the traffic flow during a time period. Additionally, will the traffic office have the basis for traditional bike-lane planning. Furthermore, because the pillars are connected to the Internet is it possible to put up reminders and encouragement messages onto displays on the columns (eco-compteur, 2013). The BCP system can be used in all sorts of situations from bike boulevards to any kind of mixed traffic on shared roads. The main benefits are that the pillar is simple and effective and customizable with maps, pictures, text etc. to be applied at specific situation at any locations. The pillar is dimensions are 230x46x16 centimetres. This system will be installed on the bicycle paths or mixed traffic roads to count bicyclists. The traffic authority of the municipality will manage and operate the system.

Figure 34: Illustration of the Bicycle Counting Pillar (eco-compteur, 2013)

Purpose	Traffic flow	**Location**	Bike lane
Power source	Power grid	**Operator**	Government
Communication	GPRS/3G	**Current usage**	Varberg, SE

5.3.2 Cycle Counting Station

Purpose

The purpose of this system is only data collection for the local traffic office. This solves the demand for traffic flow information that local traffic offices are calling for.

Application description

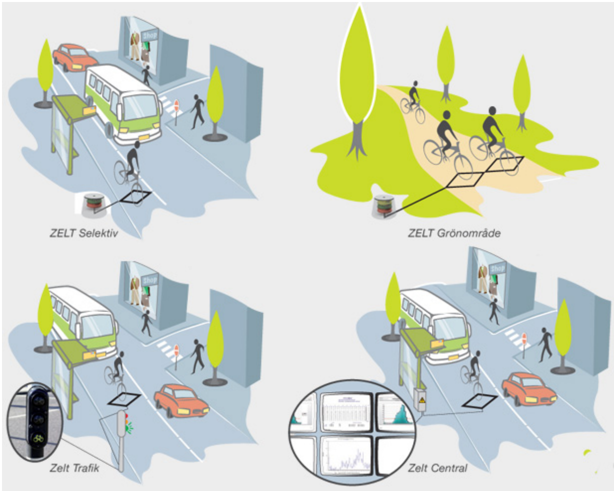

Figure 35: Illustration of the cycle counting station in a variety of situations (EcoCounter, 2012)

In addition, this Cycle Counting Station system is counting the traffic flow on bike lanes but this due not broadcast the information on pillar displays (Amparo, 2013b). The battery life is between two and four years. The station detects bicyclist by an inductive loop tube that is placed on or below the asphalt surface (see figure 35). The station is placed on the surface beside the bicycle path. The recognition signal from the inductive tube is analysed by an algorithm that determines the direction and if it's an independent bike or a cluster of riders. The information is transmitted to a central server hub by Bluetooth, GSM network or satellite phone. The information can be accessed thru a web browser and there can the information be analysed. The cycle counting station can cover a road width of about 3 meters (EcoCounter, 2012). Furthermore, the system can be used in different situations; the system can be uses at gravel roads, counting bicycles on bike paths with great accuracy (even for large groups of cyclists), identifies bicycles in mixed traffic and can control traffic lights. Also, the system is designed to fit inside a manhole for easy instalment. Furthermore, pneumatic tube sensors can also be used to detect bicyclist and it has an accuracy of +/- 5% and can be used at speeds up to 42 km/h (eco-compteur, 2013). The system can be placed at any location were bicyclists need to be measured. The local traffic office or a private company manages the system.

Purpose	Traffic flow	**Location**	Bike lanes
Power source	Batteries	**Operator**	Government
Communication	GSM	**Current usage**	-

5.3.3 Pyroelectric counting sensor

Purpose

The intention with this counting system is to detect the number of people that passes the station in a non-intrusive manner.

Application description

Figure 36: Illustration of the pyroelectric sensor (EcoCompteur, 2013)

The pyroelectric sensor is designed as a lens, which is sensitive to infrared radiation emitted by a human body, registering each person crossing (EcoCompteur, 2013). The sensor must be installed in a place where people can move without hindrance in the movement and no obstacles between the sensor and the people. The pyroelectric sensor should be positioned so that the sensor is at 80 cm height. Masking effects can occur when two or more people are next to each other: use a correction factor (manual registration) or reduce the passage width for increased accuracy. The system can detect and count directions if a person enters and exits a zone and the system can also detect pedestrians in shared areas as can be seen in figure 36. The system has a range up to 6 meters and with this a narrow operating range that can detect two persons at short intervals. At the broader passages can two lenses be installed as in and out direction. Pyroelectric sensor can be easily installed and moved and has a battery life of 10 years and is entirely self-governing. The system has a data storage capacity of more than 10 months. A GSM modem can be connected, if the option of remote measurement is desired. A custom installation kit offers flexibility and allows installation on any posts. The counting system is portable, comprehensive registration facilities for pedestrians and cyclists. The system can be used for identification of peak traffic, estimation of bicycle traffic on sidewalks and intersections etc. This intelligent system can be installed at any location and it is also mobile if data from different locations is asked for. The traffic office at the local municipality/City generally manages the system.

Purpose	Traffic flow	**Location**	Mobile
Power source	Battery	**Operator**	Government
Communication	GPRS/GSM	**Current usage**	-

5.4 Providing information

There are software applications that are accessible on the web and smartphones thru apps. However, due to the large variety of applications will only the main functions and examples be presented in this thesis.

5.4.1 Web and App based systems

Route-planers are among the most popular services for bicyclists and there are local and global companies in this field that compete to give the best information and experience as possible. A global application that is both web and app based is Google Maps. Google Maps provides directions, Street View, Search and more. The local equivalent to the previous application is trafiken.nu that provides traffic information about accidents, traffic flow and route planning. Furthermore, some route planner apps can avoid cobblestones, tram track or very busy roads that can be a potentially dangerous situation for cyclists. Additionally, there are services that provide information about biking trails for people that own mountain bikes (Total Square, 2013).

There are some applications that could help cyclists with their training. The smartphone app can track the bicyclist's speed, distance and location. The tracking is done by the smartphones GPS. The information is stored on the device or is uploaded to a server. The information is displayed on the smartphone or on the web and the data is presented on a map or by charts. An example of an app is the Swedish smartphone application "CykelAppen" that can provide the information that is described above (CykelAppen, 2013). Smartphone application can also track your health and track your exercise, weight and calorie consumption (LiveStrong, 2013).

Internationally there are several smartphone applications where the road-users can report problems with the bike-network. A Swedish alternative is cykelrAPPorten.se that is both a web and smartphone based application. Citizens can report dangerous situations, e.g. snow/ice, potholes etc. Also, an action form the local traffic office will follow up the reporting. In this way will the public be involved and be keeping the city liveable and safe. Citizens Connect is the City of Boston's effort to empower Boston residents to be the City's "eyes and ears" throughout the neighbourhoods (City of Boston, 2013). Through this application, can people now use their mobile phone in five different ways to alert the City of Boston about issues such as potholes, ice clearing etc. The biggest benefit with these applications is that they can improve the road network.

There are several applications that provide different kind of services on the road. A local example from Gothenburg City is ‘PunkApp’. It’s a free smartphone app that provides information were to find pump-stations and Bike-sharing stations (PunkApp, 2013). Weather information is also important for bicyclists and there are many local and global alternatives. The application can provide whether information about temperature and sun/rain/wind/snow information for different times (Appadvice, 2013).

Important applications are those who are intended to prevent accidents. There are websites that is profiled to prevent pedestrian and bicycling fatalities and serious injuries by providing information on places where these problems have occurred (CrashStat, 2013). The information is presented as a map on a homepage where a legend presents the different meanings. Some apps are intended to increase knowledge and promote safer traffic behaviour. This application for smartphones can provide cyclists with all kind of information about cycling and safety and the road. An international app is called ’Bike Safety’ and it provides information about traffic safety (Stroika, 2013). The application provides how to cross the road, to turn at junctions, how to interpret road signs, the correct clothing to wear and much more. Furthermore, the app informs the road user about techniques, rules, laws and best practice tips about traffic safety.

There are other apps that can help provide information about ’how to repair your bike’. There is an international smartphone application, Bike Doctor, that provides information on how to maintain your bike (Bike Doctor, 2013). The application is aimed towards people that don’t have much experience with bike repairment. The benefits with this sort of application are that it save money on bike shop repairs, know how to detect problems and repair any issues that arise. By increasing the knowledge on ‘how to safety check your bike’ increase the traffic safety. The app includes how to; how to repair and prevent punctures, how to detect if your bike pads are worn out and replace them, how to clean your bike and how to replace brake and gear cables etc.

Online shopping for a new bicycle or bicycle parts can be done by a smartphone or web store. Amazon.com is an international website were you can look for new bicycles in their inventories (Appadvice, 2013). The site offer different kinds of bicycles as mountain bike, road bike, comfort bike, cruiser, specialty, or a hybrid bike**.** There are several other options if a person wants to buy used bicycles. Craigslist.com or the Swedish equivalent Blocket.se can provide that need. The service provides people who want to sell their bikes and biking gear. There are lots of web and smartphone systems that can increase the accessibility to a bicycle or repair the existing bike to have access to the bicycle network.

5.5 Systems on the verge

On the horizon are intelligent transport systems that are in development or prototypes in the working. The developments in this area are about communication between the cyclist and the infrastructure as well as cyclist and other vehicles. By detecting the road users and alert them in the times of danger or intervene to protect people. Global positioning systems (GPS) in smart-phones and other devices will increase the knowledge about the traffic system when it comes to dangerous locations, travel speeds or acceleration/deceleration and positions. Integration of devices into the frame of the bike or as devices will enable more information to be gathered to serve the road user. LED-light have improved in recent years and are expected to be more efficient and can therefore be used more in the infrastructure. Another area of intense interest is interactive infrastructure that adapts to the environment to ensure the safety of the road users (SafeCycle, 2012).

5.5.1 Speed Vest

Purpose

The idea of this Speed Vest is to show the vehicle behind the bicyclist how fast the bike is traveling to increase traffic safety as can be seen in figure 37 (Speedvest, 2013).

Application description

This is a prototype project that is not in production. Also, the vests have the intention to increase the awareness of bicycling and promote the bike as an efficient way of travel (Speedvest, 2013). Test with the Speed vest has shown that the average speed is between 15-25 km/h for an average person. The system is designed with a wheel speed sensor, a small computer and a wearable numeric display (Mykle, 2007). The computer is an open-source project that is powered by and Amtel microcontroller with a (9 volt) battery with battery life of 6 hours. The displays on the vest can last for 6 hours with standard AA batteries. The numbers on the vest is made from electric wire tubes with a small current that is flexible and fairly durable. However, the speed vest does not have any communication equipment and can therefore not transmit information and it cannot store any data as well. Furthermore, the individual cyclist will manage and operate the system at their own expense.

Figure 37: Picture of a prototype Speed Vest (Bikeradar, 2011)

Purpose	Speed indicator	**Location**	Mobile
Power source	Batteries	**Operator**	Private
Communication	-	**Current usage**	-

5.5.2 OpenBike System

Purpose

The OpenBike project is intended to provide bicycles to people that don't have access to a bike. The system will provide a bicycle at any time at any location.

Application description

The parts included in the bicycle can be seen in figure 38. The OpenBike system has no fixed parking stations where bikes can be locked. Each bicycle itself has its own lock and it unlocks with an electronic smart card (RFID-chip) or a NFC equipped mobile phone (OpenBike, 2012). Hence, the bike has an integrated RFID-chip reader. The locks are electronically controlled and integrated to the unit. The bike is equipped with an integrated device that reports statistics and position from a built-in GPS. The bike has a GSM/GPRS-module for communication with a central system. LED-lights are built into the frame to minimize vandalism. Also, the lights are equipped with sensors that sense if it's dark and if the bike is in motion. If the bike is in the dark and moving will the lights turn on. The chain is made of the same type as the fan belt of a car to prevent issues with oil that can stain the rider's clothing. One major difference compared to other systems is that the rider can park the bike in standard bicycle rack.

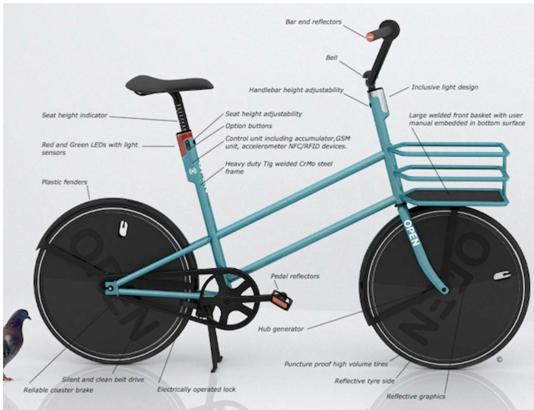

Figure 38: Illustration of the OpenBike bicycles (Inuseful, 2013)

Figure 39: Illustration of the different variety of bicycles in the OpenBike project (Inuseful, 2013)

Many cities today lack statistics on how bicyclists move in the city. Municipalities that support the OpenBike system can get statistics from the bikes GPS to improve the traffic network. In addition, the bicycles have accelerometer that measures movements and shocks. The accelerator will sense if the bike is in motion and block the locking mechanism for safety. The OpenBike system gets power from an integrated hug-generator (that produces 2-3W in motion) that is stored in an accumulator. Lastly, the bike can identify if a bike is being abused, involved in a crash or moved without authorization and send warning- and position signals in these cases. There are several different bicycles in the ecosystem for different use (see figure 39).

Purpose	Accessibility	**Location**	Mobile
Power source	Generator	**Operator**	Government/Private
Communication	GSM/GPRS	**Current usage**	-

5.5.3 CopenhagenWheel

Purpose

The aim of this device is to provide a better solution compare to the internal/external batteries that is connected to a motor on current electrically assisted bicycles.

Application description

Figure 40: Picture of the CopenhagenWheel prototype that is mounted on a standard bicycle (Popsci, 2009)

This is a structure that contains a motor, batteries and an internal gear system that is fitted into an ordinary bike wheel as can be seen in figure 40 (MIT, 2010). The weight is not more then an ordinary 'heavy bike' and the wheel gather energy by pedalling and braking. In addition, the CopenhagenWheel is equipped with location- and environmental sensors that are powered by the battery. The sensors can provide the bicycling data to a smart-phone via Bluetooth as can be seen in figure 41. Furthermore, even more equipment can be installed if needed. The information that the bike collects can be donated to the municipality and can therefore have crowed sourced cycling data to improve the bicycle paths. There is an anti-thief system on-board. To unlock the bicycle must the owner, with his/her smartphone, be at close range of the bicycle.

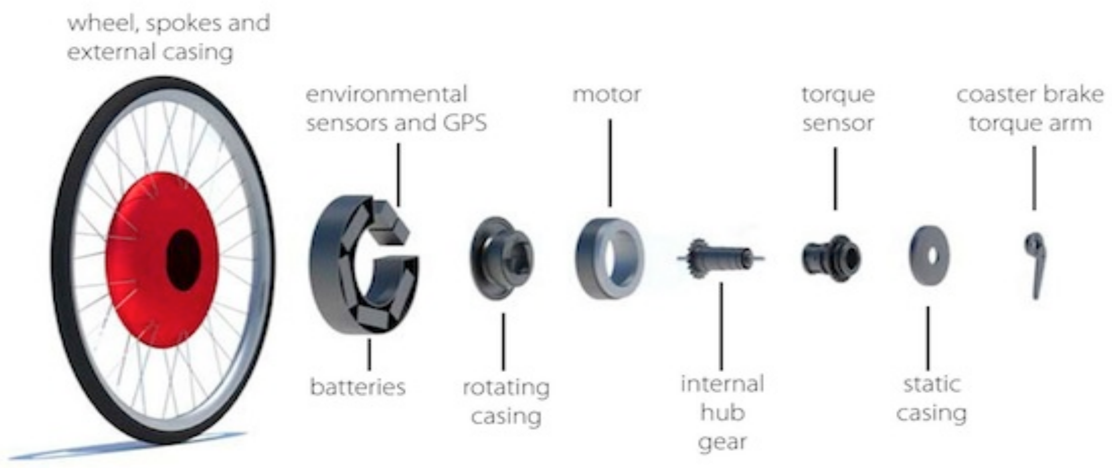

Figure 41: Illustration of the part in the CopenhagenWheel (Greenopolis, 2013)

Purpose	Improve range	**Location**	Mobile
Power source	Battery	**Operator**	Private
Communication	Bluetooth	**Current usage**	-

6 ANALYSIS

By analysing the bicyclists comments and facts in chapter 4 and structure the notes into a mind-map structure to get an overview of the bicyclists actual needs (see appendix C), have the following basic transportation needs been identified:

Connectivity

Connectivity is described as the amount of linkages between two or more points in space. The connectivity of a location increases by the increased number of links it has to other locations. Connectivity in a traffic sense is the physical roads that represent the linkages between the points of interest.

Accessibility

The definition of accessibility is described as the amount of people that have access to the network. In terms of bicycling traffic are people who have access to a bicycle able to use the bike network. Hence, if a person does not have access to a bicycle has that person not accessibility to the network at hand. In addition, the mode of transport is also in close relation with comfort and safety.

Information

Information is defined as the access to knowledge about the bicycling network for the individual that uses the network. Traffic knowledge can be granted to travellers that are provided with information about distance, time to destinations, increased navigation as well as points of interest. Bicyclists also have a desire to share their information to give a basis for improving the network.

Safety

The definition of safety in this thesis is the risk of physical damage to the bicyclists. An example is; a bike path with low safety can be dangerous to people's physical health. Hence, a road with high safety has low risk of injury to the individual. Traffic safety is a vital part of the system and can put limitations on the other needs.

Comfort

The definition of comfort is described as the mental experience of a specific location or trip. The comfort level is a personal opinion for every individual and can be described as the psychological well being of a person at a particular time. In addition, a decreased comfort level can be an effect of bad physical infrastructure or vehicle as well as uncomfortable weather conditions and physical exhaustion etc. Comfort should not be confused with safety were a traffic situation can be perfectly safe but for the individual that experience the situation can it be uncomfortable. An example of this is a person that is afraid of heights that bicycle over a bridge that is safe.

Time

An essential need for the bicyclists is travel time. By definition is travel time equal to the distance divided by the speed at witch the cyclists travel. Travellers seek to get to their destination at the least amount of time and not at the highest speed. Furthermore, in the traffic system is speed also connected to traffic safety were as an increased speed could lead to a decrease in traffic safety.

People have expressed several oppinions that is aimed towords the munisipality. However, these requests are not part of their basic transportation needs because this request is only aimed to enpower the six basic needs. All the basic transportation needs is in a way enabling or disabling each other and this builds up a linkage structure between the six nodes. Connectivity and accessability is the foundation were the others build uppon and without them cannot a trip be made. However, comfort and safety can put demands on the mode of transport and on the roads which may result in another choice of transportation. Information is a wide field that mostly enhances the other needs, because if the other transportation needs are well meet to the users standards would the information have limited affect. Time/Speed is often the the end results after putting limits on other factors such as safety and comfort. To sum up, unlimited safety and comfort lead to unlimited speed.

People value the basic transportation needs differently and therfore will different limitations be implemented to fulfill the primary desires for the individual. Hence, strains will be put on the other basic requests to increase the prioritized. For example; Senior citizes prioritise comfort/safety and the younger generation prioritise speed/time and this will affect the other. However, the physical development of the individual will also put priority and limitations on the basic transportation needs.

Safety is a key element in the model because it's in direct correlation with the individuals health. This basic need can sometimes be undervalued or overestimated and this will lead to 'chance taking' because people feel that they are still in a safe situation when in reality they have overstept the boundries. Experience and carefullness are qualities that will increse the overall safety. Because the experience will give the bicyclist a better understanding of the level of safety in a perticular situation. Carefullness has the quality that the person have more controll over the situation in a way that the person can quicly indicate that he/she has entered a dangourus zone and can therefore affect the situation accordingly.

In table 2 below is a summary of the main linkages between the bicyclist's basic transportation needs and the discovered systems. There is lot of systems that aimed towards increased safety, in terms of collision, and this might be explained by the fact that traffic safety is one of the most important issues to reach the non-deaths in traffic. However, single accident are the most common accident were falling injuries are the dominant and there is only one ITS system that is designed to prevent these accidents, solar road studs. The detector systems at traffic lights and Green Wave is designed to increase safety, speed and comfort by giving priority to the bicyclist at intersections and these systems meet many requirements from the bicycling community.

There are few systems that are aimed to increase the accessibility for people who do not own a bike and/or people that want to protect it. These two systems solve different needs. The bicycle sharing system provides a bicycle to people so they have an entrée to the bike network. Protected- and Guarded bicycle parking are aimed to protect the person's bike and therefore her/his accessibility.

Few ITS systems can meet the information need and the web and app-based system best positioned. However, RFID-chip, traffic light countdown, and counting systems provide the municipality and the bicyclists with specific information. In addition, smartphone applications are intended to provide information to the bicyclists and that knowledge influences all the other transportation requests. Smartphones can have a rout-planner applications can provide a bike path that is safe, comfortable with the least amount of travel time. Service applications can provide information about bike repairment, pump stations, bicycle sharing stations etc. and this increases/keeps the accessibility for the bicyclists. At last, the applications that focus on reporting problems with the network or collecting tracking data can improve the connectivity by giving the bicycle network a higher quality. Additionally, municipalities can embrace all the third-party applications with their full support or they can get inspired of the functions and develop their own applications.

Table 2: The main correlations between the bicyclist's basic transportation needs and the ITS systems

SUMMARY							
Information: x = correlation		Connectivity	Accessability	Information	Safety	Comfort	Time
	Bicycle-based systems						
5.1.1	Airbag helmet				x		
5.1.2	Bicycle breaking light				x		
5.1.3	Bicycle sharing system		x				
5.1.4	Electrical assisted bicycles					x	x
5.1.5	Guarded bicycling parking		x				
5.1.6	LED lights on wheel spokes				x		
5.1.7	Protected bicycling parking		x				
5.1.8	RFID-Chip-Tag			x			
	Managing traffic						
5.2.1	Enhanced Warning at Crosswalks (EWaC)				x		
5.2.2	Green Wave				x	x	x
5.2.3	Intelligent road studs				x		
5.2.4	Intersection warning system				x		
5.2.5	LED-lane road studs for right turn				x		
5.2.6	Motion detection system				x	x	x
5.2.7	Pre-green traffic light				x	x	x
5.2.8	Rain-sensitive traffic light					x	x
5.2.9	Right-turn-warning system				x		
5.2.10	Solar road studs				x	x	
5.2.11	Traffic light countdown			x	x		
	Monitoring traffic						
5.3.1	Bicycle Counting Pillar (BCP)			x			
5.3.2	Cycle Counting Station (CCS)			x			
5.3.3	Pyroelectric counting sensor			x			
	Providing information						
5.4.1	Web and App based systems	x	x	x	x	x	x

7 DISCUSSION

The bicycle have a bright future ahead, because every level of government wants to increase the number of bicyclists and this will lead to further development. The Swedish Transport Administration have implemented the four-stage-process and this gives ITS an advantage because the first two steps include ‘re-think’ and ‘optimize’ that aims to make existing infrastructure more efficient. I think that a devoted road office that believes that ITS can make a positive change is vital to the success of the systems. In addition, municipalities must be committed to support the system long-term to insure the success otherwise will ITS not reach its full potential.

What does the bicyclist need? If we look at the physical development in the age groups can we numerous different needs. I believe that children around seven years old have problems to understand the traffic safety issues at hand. Therefore, vehicle traffic and bike roads should be detached to increase traffic safety. Another key issue is to get children to start bicycle in an early age. There is no intelligent system that is directly focused on kids, but the motion detector systems can make a difference at intersections. At the end must the traffic speed around school must be reduced to compensate for the lack of children’s traffic sense. In the mid-range adults (between 18-65 years) are the bicyclists in their physical prime and they are therefore not limited by their physical development. Furthermore, the senior citizens physical performance start to be reduced at an older age and the main areas are a reduction in balance and muscular strength. Older people have therefore a harder time handling the bike and this leads to more falling accidents that is especially dangerous for older people that are more frail. Additionally, a key issue is when seniors get on/off their bike. A solution to this can be to reduce this action at traffic light intersections with ‘Green Wave’ and ‘Detector systems’ that is designed to give priority to bicyclist at intersections. If seniors can be seated during the whole trip could it reduce the falling accidents among seniors.

In the statistics of bicyclist accidents, in chapter 4.2, show that bicyclist have most injuries that lead to permanent disabilities. The main reason for the accidents are single accidents due to falling and here is a slippery road surface to blame. Hence, the main reasons for falling are because of snow, ice, sand, gravel, leaf and glass. There are no ITS system that can remove the items above but report-problems applications can indirectly help this problem. However, regular maintenance is a major item for improvement to ensure the safety for the cyclists. Problems with light are an additional drawback for bicyclist and an in-expensive solution can be solar road studs along the bike path. The small LED-light can be placed at any location in the pavement and get charged from sunlight. Furthermore, there are problems with collisions with motorized vehicles at intersections. The ‘right-turn-warning’ system can sense the presence of a bicyclist at an intersection and indicate that to the driver of the vehicle and the bicyclist. LED-lane road studs for right turn are another system that can improve the traffic safety cyclist in the intersection.

Motion detector systems have the purpose to give priority to the bicycle. However, that there are some ideological issues that must be resolved in the municipalities. First is the question if the bicyclist should have a higher priority then cars. Secondly, how much priority shall the cyclist have? For instance, shall one cyclist have more priority over the cars at traffic light intersection or shall many cyclists at the same intersection have priority over vehicles. Furthermore, there is also an issue if the whole bike path shall have priority as can be seen with the Green Wave system. During which times shall the cyclist have priority? Last, if the traffic light prioritizes bicyclist over vehicle traffic, then is the question of how long shall the time of the green light be? I believe that if the bicycle gets a higher priority will this lead to a higher status of the bike as a first mean of transport and this will increase the bicycling population.

A key element to increase the number of bicyclist is to increase the awareness of the possibilities. I believe that campaigns and commercials could help to get the massage out to people about the traffic system and bicycling. However, the message must have content to lean upon to get traction. The content could be a reliable app and web services that contains the entire elements of what the bicyclists ask for. However, I believe less is more, therefore should local traffic offices invest in services that give the best quality and not quantity to the road users. Navigation, services and report-problems are the most important applications for users. With report-problems applications can citizens report issues and give ideas to improve the network. An example is to report problems with curbstones that are a major problem for falling accidents and comfort. Local information is another important part for bicyclists and a big benefit would be if it could be personalized. However, information must be easily accessible and easy to understand and this will lead to a trust in the web/app services and people will use them again.

Some ITS systems have been gadget like and I believe that those systems should be treated as "add-on" due to the fact that the infrastructure must work without the requirement of personal equipment. A future problem can be that if an add-on system becomes common can a car driver takes it for granted that all bicyclists has this add-on. Consequently, this can be a potential danger for the bicyclist that is not equipped with this add-on.

I think that the bicycle sharing system can be used as a platform for standardization where an operational manager can add sensors and gadgets on the existing bikes. With a tracking system add-on for the bicycles can the municipality and the operational company cooperates to make the network better. The system can also be beneficial if the bikes are equipped with electric motors that can increase the rage of the bike trip and also solve the problem with hilly bike paths and personal hygiene issues. People have a desire to bring their bicycle on public transport when traveling longer distances. Additionally, with a public transport system that struggles with the strains of overcrowded busses and trams is it less likely that it will be meet. However, I believe that the bicycle sharing system can overcome this problem, because then do you not need to bring your own bike. I believe that if municipality invest in the "Bicycle sharing system" infrastructure and makes it a universal part of the public transport will it benefit the society. In addition, a well-developed infrastructure with easy access to a bike-station could increase the bicycling further. There should be larger station hubs near the public transport nodes and near work places and schools/universities to increase the commuting trips. The stations at central stations can have multi-story bike parking houses with additional services as can be seen in most central stations for public transport. However, a major problem with the bike sharing system is the lack of access to bike helmets and this can give an incentive to people to use the bicycles without helmets. The bicycle sharing systems can also prevent illegal parking because the bicycle must be returned to the station.

The Swedish Transport Administration can partner with smartphone manufacturers and telecommunications companies to have GPS data transactions to improve the traffic network. With the data can road planners make better decisions were to improve the network with data to support it. There are local traveller-planner applications today on municipality level. However, I believe that a large scale map can be better if it contains accurate local data due to the fact that bicyclist travel between municipalities. Also, if the municipality develops the travel planner map; then must the local traffic office keep updating the map with more accurate and relevant data. A good solution can be semi-open map were bicyclists can improve the information and the traffic office act as an observer.

It is important to evaluate the systems to determine if it contributes to a change in behaviour sustainable development and does not intrude on personal privacy of other ethical issues. Additional studies (before and after) must be done to see if the traveller’s attitude changes as a consequence due to new information. Also, it should also be studied if the ITS systems work with most bike designs. For example; carbon-fiber bikes is lighter and non-magnetic compare to general bikes.

Potential new systems

What is the ideal intelligent transport system without a financial limit? I believe the first objective should be a wide and automatic information collection to have the data to improve the traffic system. The permanent counting stations should be on bicycle highways and mobile counting station for quick overviews at specific locations. However, the best way this can be done are with numerous GPS trackers and a GIS map. I think that this can be done with a GPS tracker data on a GIS map. There are tree ways to do collect traveller data: First can people have a tracker on them, secondly can the tracker be integrated into the bike (in a bicycle sharing system) or be integrated into a smartphone application. This information can be used to increase the connectivity by designing roads that is less then 5 km and take less then 30 minutes.

The second objective should be to remove disturbances. Disturbance handling is an area on intense interest for both the municipality and the road users and this is were web and smartphone applications can be useful. Road-planners can direct traffic away from the disturbance. People can also report problems with disturbance in the road network by using smartphone applications. Conventional local radio station can also report on the disturbances as they do for the vehicle traffic. By providing the citizen with information and direction for planned disturbances (ex: road work) can that decrease the irritation of the bicyclist and improve the traffic flow. I think apps like cykelrapporten.se are a step in that direction.

Furthermore, there could be a region wide bicycle sharing system with electrically assisted that is fully integrated into the public transport system. The stations should be closely connected to the bicycle highways and larger workplaces. Larger workplaces, hotels, malls etc. should be able to request a bicycle station near by to make it easy to reach the destination. There should be different types of bicycles for different necessities. The bicycles can also be equipped with intelligent add-on as taillight, RFID-chip and also a place to store an airbag helmet or ordinary helmet.

At last, some people have asked for information along the roadway. There could be a display that shows distances, traffic information, promotion messages, traffic info, disturbance messages etc.

8 CONCLUSION

Intelligent transport systems shall only be an extra layer of effectiveness on top of the physical traffic infrastructure, due to the systems reliability to electricity and communication that is not universally granted. Hence, if the electricity stops working must the physical infrastructure take the task as with traffic light intersection and the right-hand-rule.

ITS systems that are non-part of the infrastructure should be seen as personal vehicle improvement. Nevertheless, if some non-infrastructure systems are applied on a ‘Bicycle sharing’ system at scale in urban areas, then could those be a part of the bicycle infrastructure. Bicycle sharing managers could collaborate with local road offices to improve the bikes with proven gadget add-ons to increase traffic safety. The add-ons can be intelligent breaking light, electrical assisted, RFID-chips and a place to store an airbag helmet.

The ‘Bicycle sharing’ system is a platform as a mean of transport in the same way as city busses and should therefore receive the same benefits. The benefits are; an all connected network with color-coding, priority at intersections, same payment affiliation, and roof over selected stations and larger station hubs with additional services. Also, equal financial plan and a larger presence in the traffic system.

Problems/disturbances with the road network can be avoided with the help of smartphone applications. Report-problem applications as the Swedish cykelrapporten.se are a greatly important tool to use to improve the existing infrastructure. Smart route planning- and service applications are also an important to keep and attract more bicyclists.

The thing that people ask for the most is not an intelligent transport system. Bicyclists dream is to have an all connected bike network that is separated from other modes of transport. The roads should be as straight as possible with street names and color-coding. In addition, the road surface must be a clean from snow, sand/gravel, glass etc. and have a good quality with no potholes, cracks etc.

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10 APPENDIX A. Four-Stage-Process

Fyrstegsprincipen

Trafikverkets aktiviteter spänner över ett brett område. Gemensamt för dem alla är att de faller in under en arbetsstrategi som vi kallar fyrstegsprincipen.

Varje enskilt steg i fyrstegsprincipen täcker in olika aspekter och skeden i utvecklingen av transporter och av vår infrastruktur.

Fyrstegsprincipen

1. **Tänk om**
   Det första steget handlar om att först och främst överväga åtgärder som kan påverka behovet av transporter och resor samt valet av transportsätt.
2. **Optimera**
   Det andra steget innebär att genomföra åtgärder som medför ett mer effektivt utnyttjande av den befintliga infrastrukturen.
3. **Bygg om**
   Vid behov genomförs det tredje steget som innebär begränsade ombyggnationer.
4. **Bygg nytt**
   Det fjärde steget genomförs om behovet inte kan tillgodoses i de tre tidigare stegen. Det betyder nyinvesteringar och/eller större ombyggnadsåtgärder.

Hållbart resande lägger tyngdpunkten på de två första stegen, som handlar om att bearbeta attityder och att framhålla och marknadsföra hållbara resval. Vi ser det som en viktig uppgift att föra en kontinuerlig diskussion om hur resandet kan optimeras så långt som möjligt .

Senast uppdaterad/granskad 2012-08-30

Figure 18: Fyrstegsprincipen, http://www.trafikverket.se/Foretag/Trafikera-och-transportera/Planera-persontransporter/Hallbart-resande/Fyrstegsprincipen/

11 APPENDIX B. Accidents in Sweden

Folksam Datum 2012-05-04 Sid 1(3)

Bilaga. Cykelskador – kommunernas vanligaste trafikskada

Tabell 1. Antal skadade i tätbebyggt område, i nio stora städer, som rapporterats till akutsjukhusen under år 2010-2011.

Antal skadade personer	Göteborg	Jönköping	Linköping	Lund	Malmö	Norrköping	Stockholm	Umeå	Västerås	Totalt	ALLA TÄTORTER I SVERIGE
Cykel	731	94	238	723	1288	371	1225	1023	722	7210	16756
Fotgängare	167	26	33	47	164	18	310	61	58	1011	2183
Buss	59	12	4	12	77	40	98	38	16	431	606
Personbil	942	185	242	197	639	301	1451	436	480	6103	13754
MC	68	7	8	19	47	26	163	38	39	533	1306
Moped	175	29	22	27	120	47	164	110	63	906	3109
Annan	65	7	15	20	49	19	84	26	17	344	743
Totalt	**2207**	**360**	**562**	**1045**	**2384**	**822**	**3495**	**1732**	**1395**	**16538**	**38457**

Tabell 2. Andel trafikskador som leder till bestående funktionshinder (medicinsk invaliditet*) baserat på data från akutsjukhusen i nio stora städer i Sverige under åren 2010-2011.

2010-2011	Göteborg	Jönköping	Linköping	Lund	Malmö	Norrköping	Stockholm	Umeå	Västerås	ALLA TÄTORTER I SVERIGE
Cykel	36%	26%	44%	78%	60%	49%	41%	59%	54%	48%
Fotgängare	10%	13%	9%	5%	6%	1%	11%	4%	7%	7%
Buss	2%	7%	0%	1%	2%	5%	3%	2%	1%	2%
Personbil	36%	36%	38%	11%	22%	32%	31%	24%	28%	28%
MC	6%	4%	2%	2%	3%	3%	6%	4%	3%	5%
Moped	8%	12%	3%	1%	5%	6%	5%	6%	5%	8%
Annan	3%	3%	4%	1%	2%	5%	2%	2%	2%	2%
Totalt	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Folksam Datum 2012-05-04 Sid 2(3)

Tabell 3. Antal trafikskador som leder till bestående funktionshinder (medicinsk invaliditet*) baserat på data från akutsjukhusen i nio stora städer i Sverige under åren 2010-2011.

Antal skadade personer	Göteborg	Jönköping	Linköping	Lund	Malmö	Norrköping	Stockholm	Umeå	Västerås	Totalt Tätorter i Sverige
Cykel	133	16	40	127	234	65	279	168	131	3163
Fotgängare	36	8	9	9	24	2	73	11	18	456
Buss	7	4	0	2	8	7	18	7	2	101
Personbil	133	23	34	18	85	42	212	68	68	1880
MC	23	2	2	3	10	5	41	10	8	323
Moped	30	7	2	2	20	8	36	16	11	542
Annan	10	2	3	1	8	6	17	5	3	136
Totalt	**372**	**64**	**91**	**162**	**390**	**133**	**676**	**285**	**240**	**6602**

Tabell 4. Väglag vid singel-cykelolyckor som leder till medicinsk invaliditet baserat på data från akutsjukhusen år 2003-mars 2011. Information om väglag finns i cirka 10 procent av fallen.

CYKEL SINGEL

	Torrt väglag	Vinterväglag
Antal olyckor	1678	686
Antal medicinsk invaliditet	145	156
Relativ risk	0.086	0.227

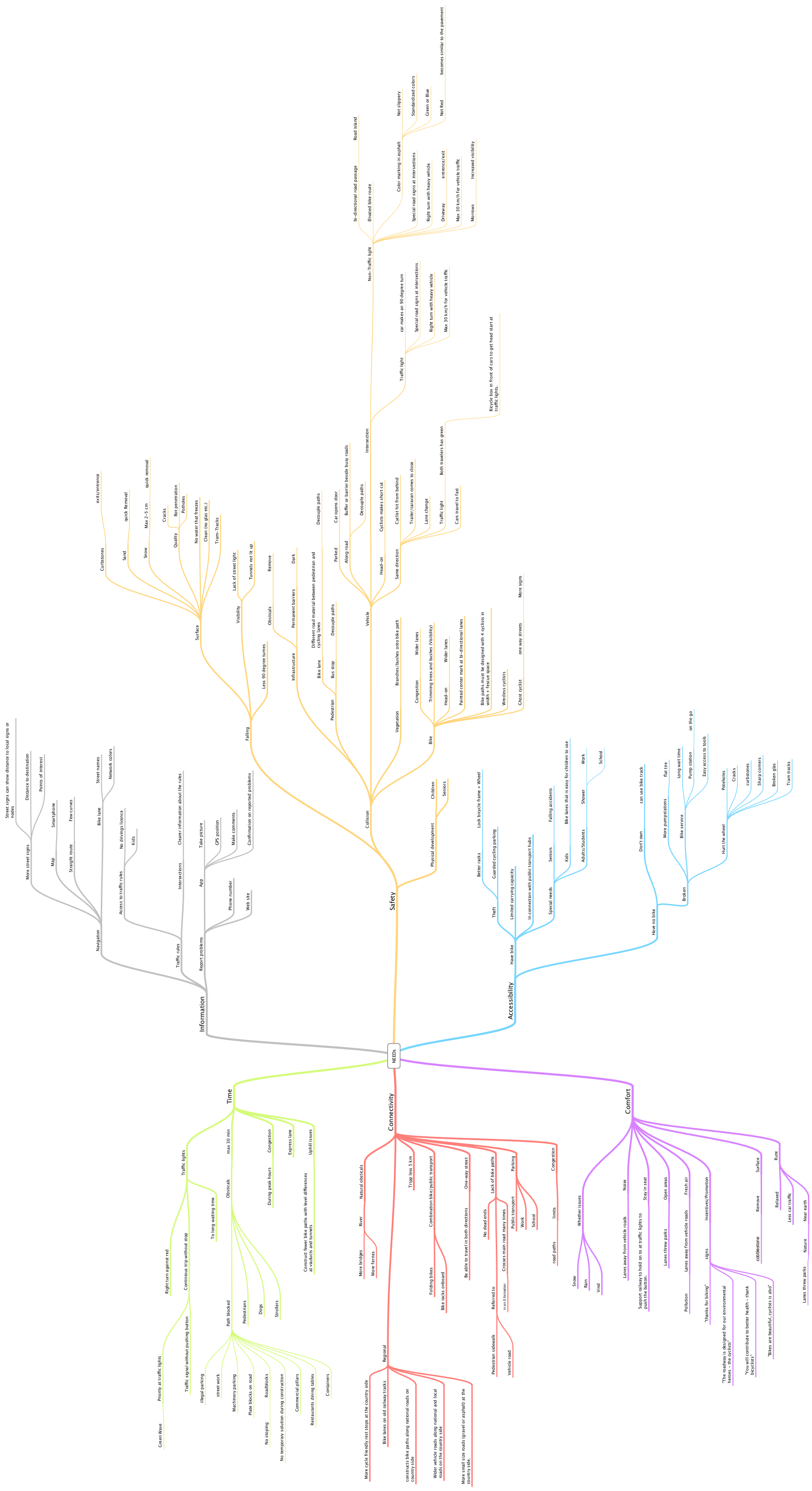
Tabell 5. Typ av olycksplats i singel-cykelolyckor, där personskadan leder till medicinsk invaliditet. Olyckor rapporterade till akutsjukhusen 2003-mars 2011.

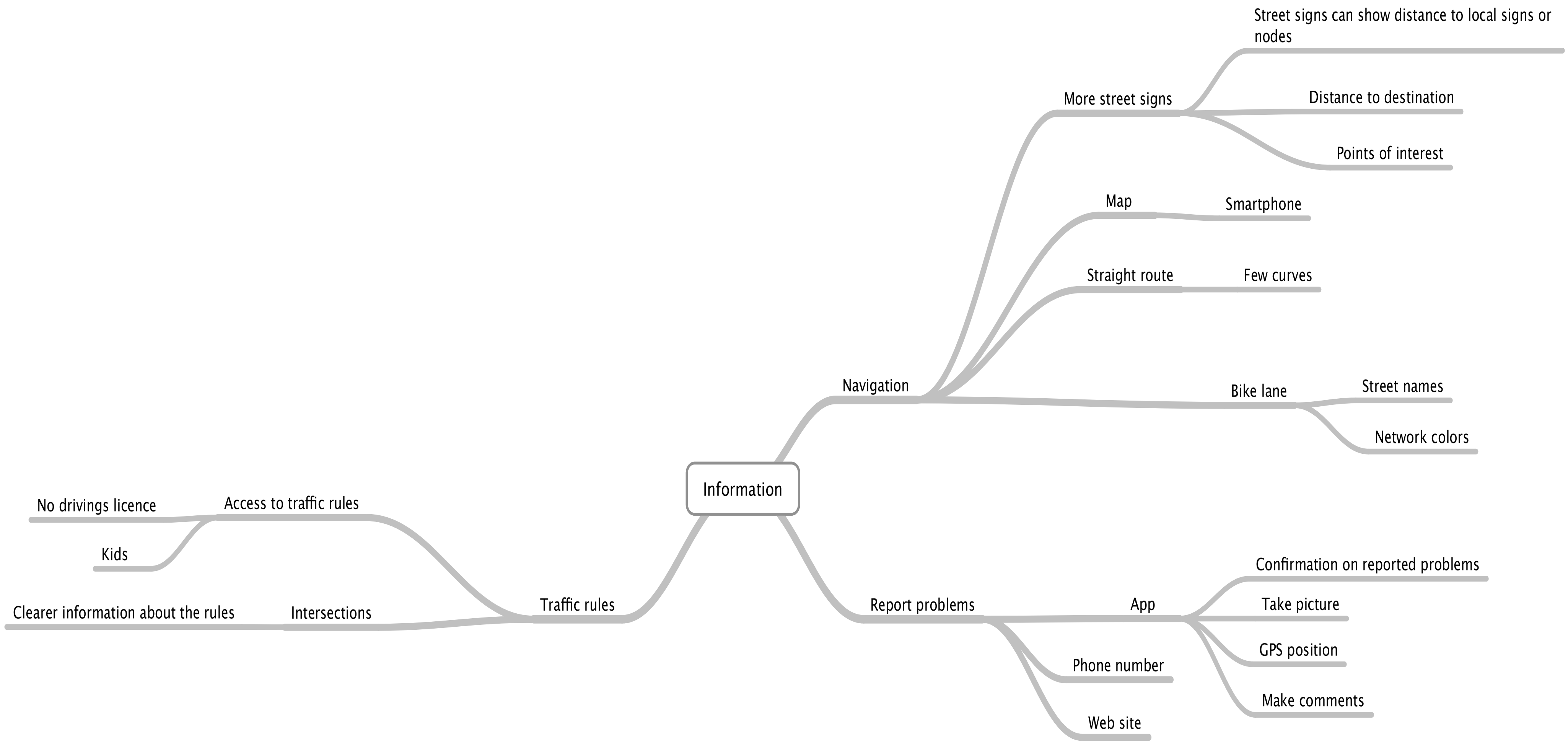
Olycksplats	
Gatu-/Vägkorsning	8%
Gatu-/Vägsträcka	39%
Gång- och cykelbana (-väg)	38%
Gångbana/trottoar	5%
I cirkulationsplats/rondell	1%
Okänd	5%
Separat P-plats	1%
Annat	2%
Totalt	**100%**

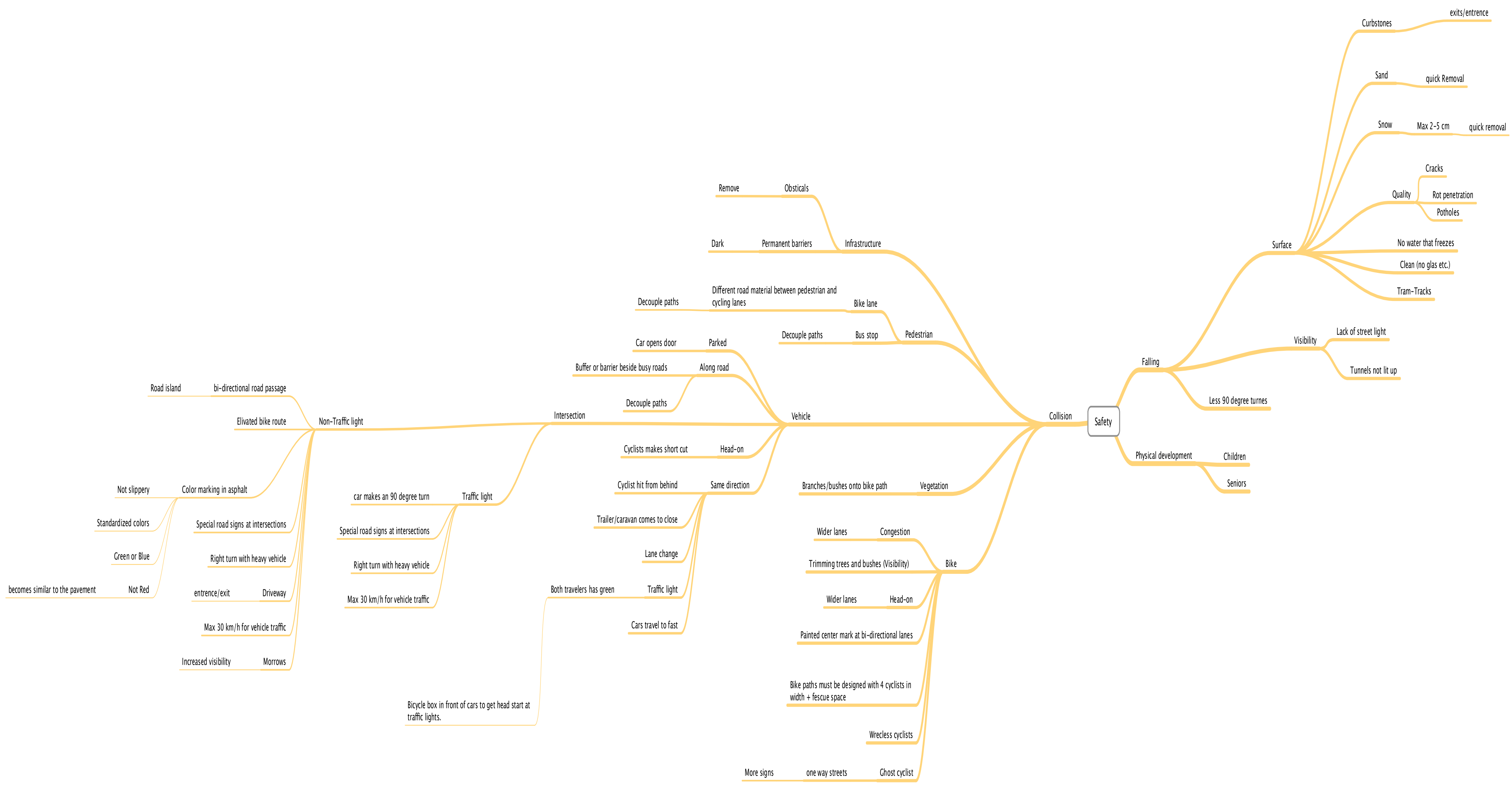
N=3677

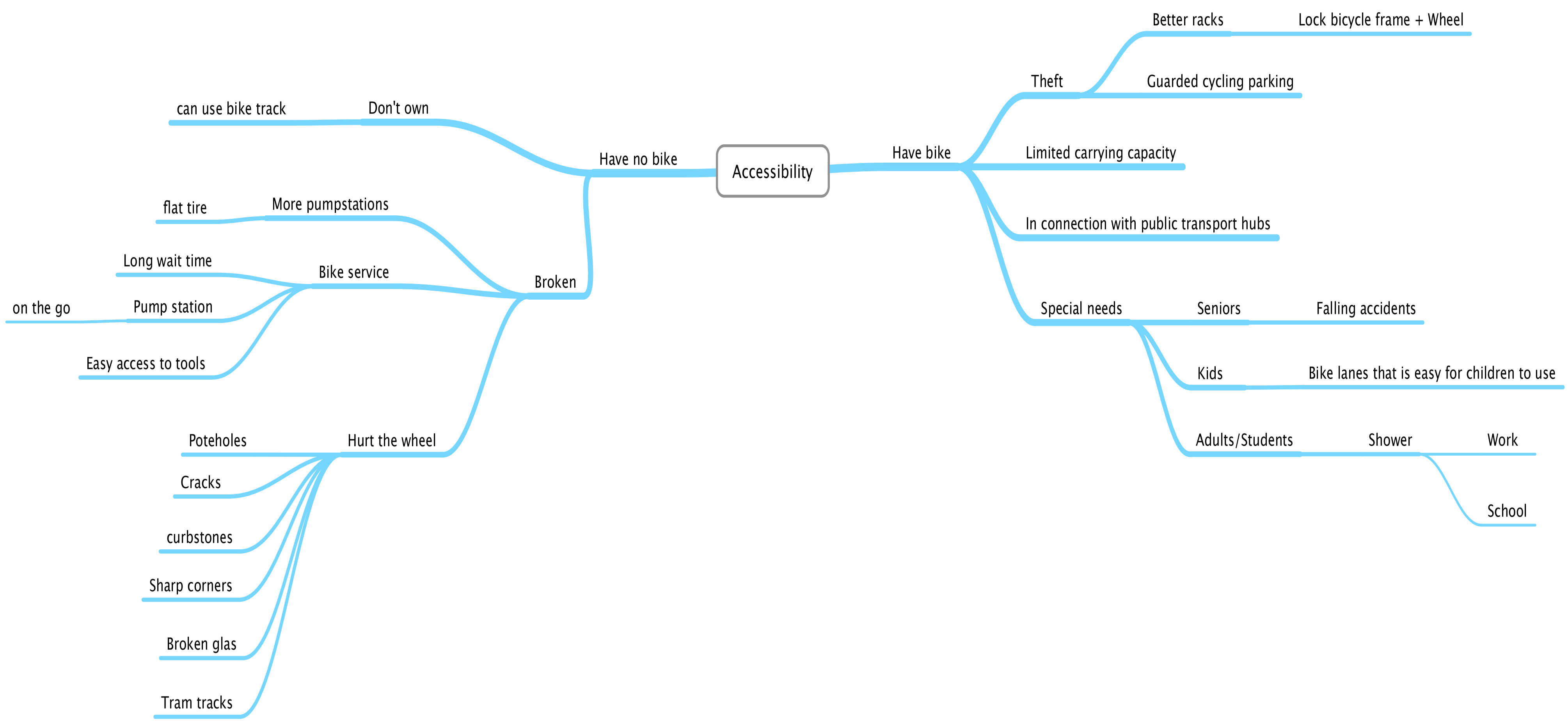
* Medicinsk invaliditet är ett nationellt mått som beskriver kvarvarande besvär efter en skada. Invaliditetsgraden kan vara mellan 1-100%, och fastställs tidigast ett år efter olyckstillfället. Försäkringsbolagen använder sig av denna metod och det nationella hälsomåttet för trafikskador grundar sig på risken för medicinsk invaliditet.

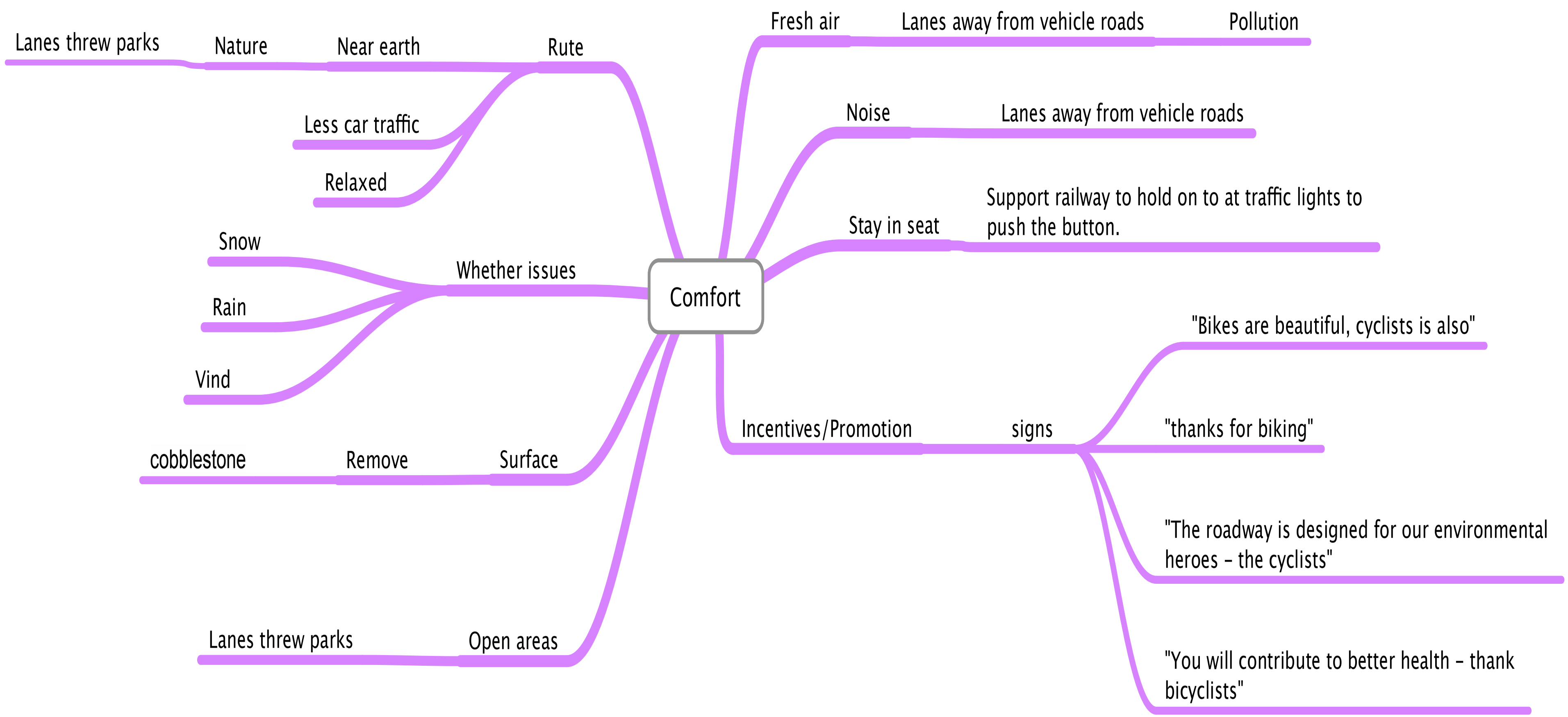
12 APPENDIX C. Mind-map of bicyclists needs

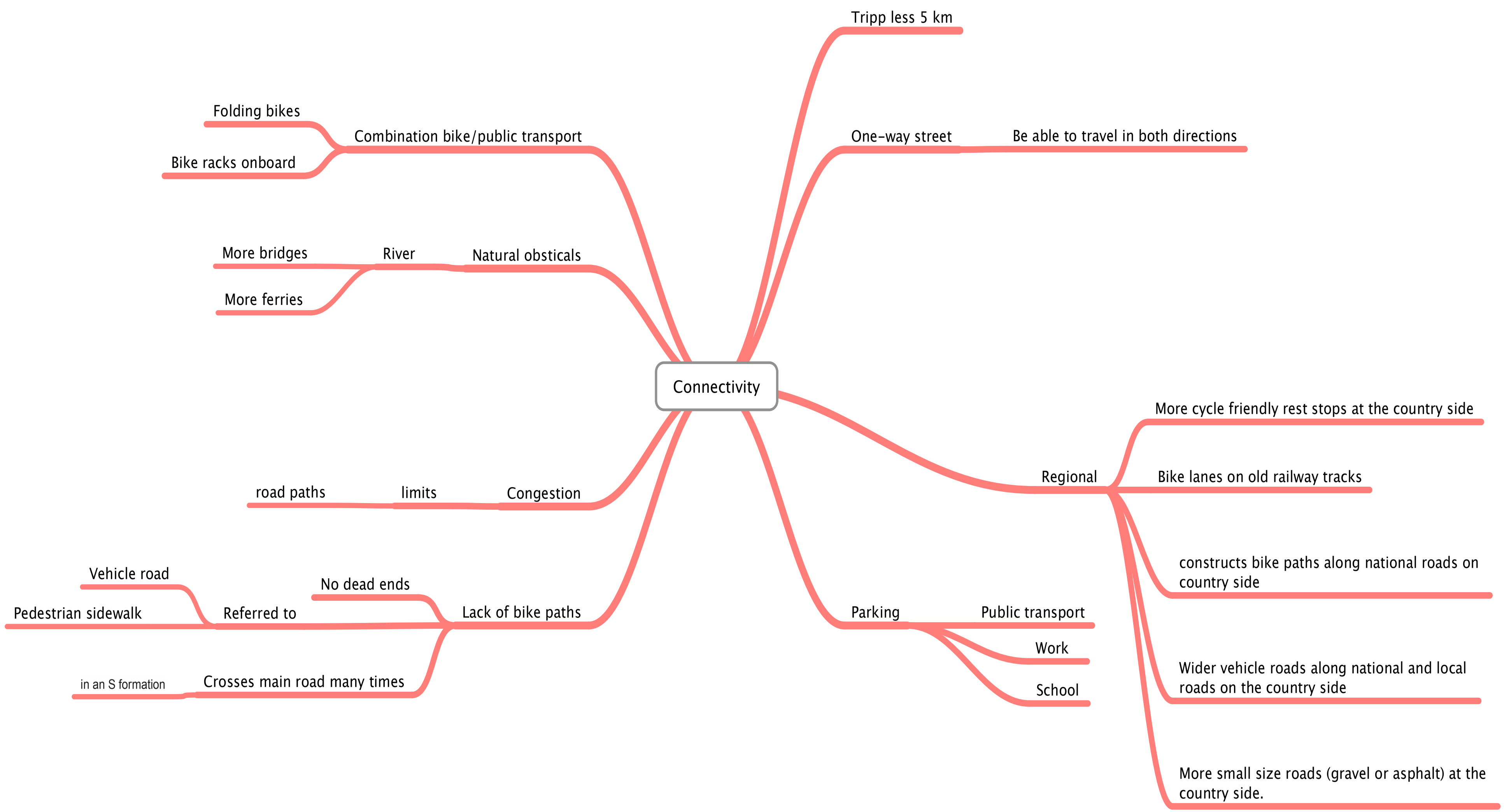


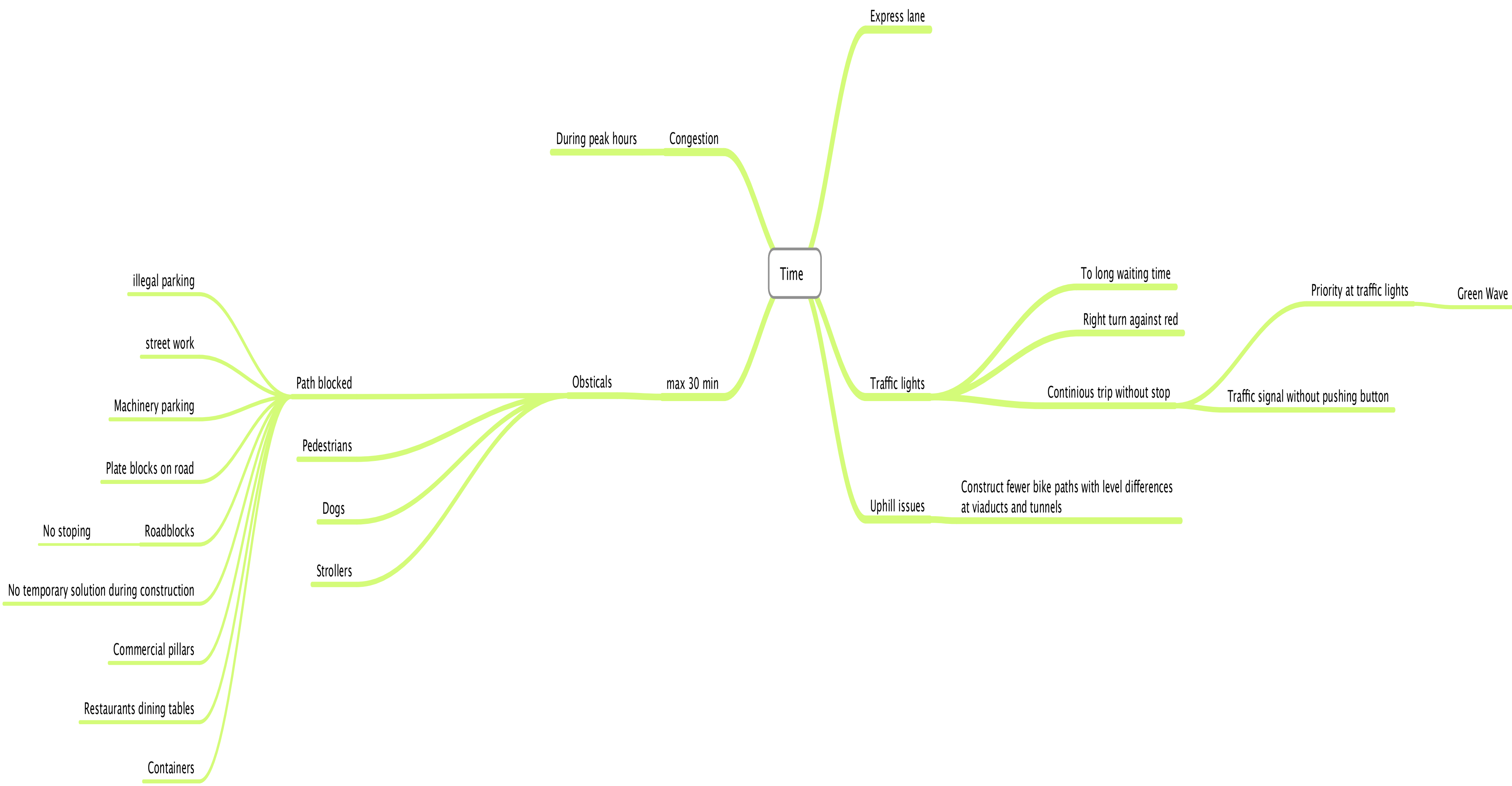

Information
Navigation
More street signs
Street signs can show distance to local signs or nodes
Distance to destination
Points of interest
Map
Smartphone
Straight route
Few curves
Bike lane
Street names
Network colors
Report problems
App
Confirmation on reported problems
Take picture
GPS position
Make comments
Phone number
Web site
Traffic rules
Access to traffic rules
No drivings licence
Kids
Intersections
Clearer information about the rules


Safety
Falling
Surface
Curbstones
exits/entrence
Sand
quick Removal
Snow
Max 2-5 cm
quick removal
Quality
Cracks
Rot penetration
Potholes
No water that freezes
Clean (no glas etc.)
Tram-Tracks
Visibility
Lack of street light
Tunnels not lit up
Less 90 degree turnes
Physical development
Children
Seniors
Collision
Infrastructure
Obsticals
Remove
Permanent barriers
Dark
Pedestrian
Bike lane
Different road material between pedestrian and cycling lanes
Decouple paths
Bus stop
Decouple paths
Vehicle
Parked
Car opens door
Along road
Buffer or barrier beside busy roads
Decouple paths
Head-on
Cyclists makes short cut
Same direction
Cyclist hit from behind
Trailer/caravan comes to close
Lane change
Traffic light
Both travelers has green
Bicycle box in front of cars to get head start at traffic lights.
Cars travel to fast
Intersection
Traffic light
car makes an 90 degree turn
Special road signs at intersections
Right turn with heavy vehicle
Max 30 km/h for vehicle traffic
Non-Traffic light
bi-directional road passage
Road island
Elivated bike route
Color marking in asphalt
Not slippery
Standardized colors
Green or Blue
Not Red
becomes similar to the pavement
Special road signs at intersections
Right turn with heavy vehicle
Driveway
entrence/exit
Max 30 km/h for vehicle traffic
Morrows
Increased visibility
Vegetation
Branches/bushes onto bike path
Bike
Congestion
Wider lanes
Trimming trees and bushes (Visibility)
Head-on
Wider lanes
Painted center mark at bi-directional lanes
Bike paths must be designed with 4 cyclists in width + fescue space
Wrecless cyclists
Ghost cyclist
one way streets
More signs


Accessibility
Have bike
Theft
Better racks
Lock bicycle frame + Wheel
Guarded cycling parking
Limited carrying capacity
In connection with public transport hubs
Special needs
Seniors
Falling accidents
Kids
Bike lanes that is easy for children to use
Adults/Students
Shower
Work
School
Have no bike
Don't own
can use bike track
Broken
More pumpstations
flat tire
Bike service
Long wait time
Pump station
on the go
Easy access to tools
Hurt the wheel
Poteholes
Cracks
curbstones
Sharp corners
Broken glas
Tram tracks


Comfort
Rute
Near earth
Nature
Lanes threw parks
Less car traffic
Relaxed
Whether issues
Snow
Rain
Vind
Surface
Remove
cobblestone
Open areas
Lanes threw parks
Fresh air
Lanes away from vehicle roads
Pollution
Noise
Lanes away from vehicle roads
Stay in seat
Support railway to hold on to at traffic lights to push the button.
Incentives/Promotion
signs
"Bikes are beautiful, cyclists is also"
"thanks for biking"
"The roadway is designed for our environmental heroes - the cyclists"
"You will contribute to better health - thank bicyclists"


Connectivity
Tripp less 5 km
One-way street
Be able to travel in both directions
Combination bike/public transport
Folding bikes
Bike racks onboard
Natural obsticals
River
More bridges
More ferries
Congestion
limits
road paths
Lack of bike paths
No dead ends
Referred to
Vehicle road
Pedestrian sidewalk
Crosses main road many times
in an S formation
Regional
More cycle friendly rest stops at the country side
Bike lanes on old railway tracks
constructs bike paths along national roads on country side
Wider vehicle roads along national and local roads on the country side
More small size roads (gravel or asphalt) at the country side.
Parking
Public transport
Work
School


Time
Express lane
Congestion
During peak hours
max 30 min
Obsticals
Path blocked
illegal parking
street work
Machinery parking
Plate blocks on road
Roadblocks
No stoping
No temporary solution during construction
Commercial pillars
Restaurants dining tables
Containers
Pedestrians
Dogs
Strollers
Traffic lights
To long waiting time
Right turn against red
Continious trip without stop
Priority at traffic lights
Green Wave
Traffic signal without pushing button
Uphill issues
Construct fewer bike paths with level differences
at viaducts and tunnels

13 APPENDIX D. Mind-map of the systems