CHALMERS
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Analysis of bicycle accidents in Karlstad

An analysis of the bicycle accidents to see why, how and when the accidents occur in Karlstad, with special focus on single bicycle accidents

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

KARL BORGSTRAND

Department of Civil and Environmental Engineering
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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2015
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Cover:
An image of one of the major bicycle paths in Karlstad. The bicycle path goes along the river Klarälven. The path is a good example of separating bicyclists and pedestrians.

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ABSTRACT

Analyses on single bicycle accidents can be found in previous studies, but they have been performed for Sweden in general. A study of the bicycle accidents in Karlstad was performed, with special focus on single bicycle accidents. The study answers the questions why, how and when the accidents occur in the city. Bicycle accidents in Karlstad during the years 2009-2013 were included in the study. STRADA (Swedish Traffic Accident Data Acquisition) was used as an information source for the bicycle accidents. STRADA is a national information system for accidents and injuries in the transport sector to which the police and emergency hospitals report accidents in the transport sector. The accidents from STRADA were compiled in Excel and analysed with support of Excel and GIS. Six classifications for the main accident causes were chosen to simplify the analysis. The six accident classifications were operation and maintenance, bicycle path design, state and behaviour of the bicyclist, the bicyclist in interaction with the bicycle, the bicyclist in interaction with other road users and accidents with an unknown cause. It is important to remember that it is only accidents that have been reported to STRADA that were compiled and analysed.

The number of single bicycle accidents in Karlstad decreased during 2010 but have increased since then. Single bicycle accidents stood for around 75% of the bicycle accidents. It can be compared with the accidents between cars and bicycles that stood for 14% of the bicycle accidents. The majority of the single bicycle accidents were minor and no fatal accident have been reported during the studied period. The most common main accident causes were operation and maintenance related and accidents with an unknown cause, which each stood for 29% of the singe bicycle accidents. The operation and maintenance related accidents were mainly due to slipperiness caused by ice, snow or sand. A significant part of the slipperiness accidents occurred in the morning around 07:00-09:00. From the analysis, it was seen that a significant part of the single bicycle accidents occurred in the central parts of Karlstad. Many road users are in motion/movement in the central parts, which was assumed to be one reason for the many accidents there. Some of the bridges in Karlstad were also quite prone to accidents. A majority of the accidents on or by the bridges was operation and maintenance related, especially slipperiness related.

Key words: Karlstad, bicyclists, single bicycle accident, bicycle accident, STRADA, accident causes, operation, maintenance, bicycle path, design

Analys av cykelolyckor i Karlstad

En analys av cykelolyckorna för att se varför, hur och när olyckorna sker i Karlstad, med speciellt fokus på cykel-singelolyckor

Examensarbete inom masterprogrammet Infrastructure and Environmental Engineering

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SAMMANFATTNING

Analyser av cykel-singelolyckor kan hittas i tidigare studier, men de är oftast gjorda för Sverige i stort. En studie över cykelolyckor i Karlstad har genomförts, med fokus på singelolyckor. Studien besvarar frågeställningarna varför, hur och när olyckorna sker i Karlstad. Olyckor som skedde i Karlstad mellan åren 2009-2013 inkluderades i studien. Statistik och information över cykelolyckor har hämtats från STRADA (Swedish Traffic Accident Data Acquisition). STRADA är ett nationellt informationssystem för olyckor inom transportsystemet. Både polisen och akutsjukhus rapporterar in olyckor inom transportsystemet till STRADA. Olyckorna i STRADA sammanställdes i Excel och analyserades med hjälp av Excel och GIS. Sex huvudklassifikationer för olycksorsaker valdes för att förenkla analysen. Dessa sex var drift och underhåll, utformning av cykelvägen, tillstånd och beteende av cyklisten, cyklisten i interaktion med cykeln, cyklisten i interaktion med andra trafikanter och olyckor med okänd orsak. Det är viktigt att komma ihåg att det är bara de olyckorna som har rapporterats till STRADA som sammanställs och analyseras.

Cykel-singelolyckorna i Karlstad minskade 2010 men har ökat sedan dess. Singelolyckorna stod för ungefär 75% av alla cykelolyckor. Det kan jämföras med 14% som olyckorna mellan cyklister och bilar stod för. Majoriteten av singelolyckorna var lindriga och ingen olycka med dödlig utgång har rapporterats under den studerade perioden. De vanligaste huvudorsakerna för olyckorna var drift och underhåll samt olyckor med okänd orsak som vardera stod för 29% av singelolyckorna. De drift- och underhållsrelaterade olyckorna berodde främst på halka orsakad av is, snö eller sand. En betydande del av halkolyckorna skedde på morgonen runt klockan 07:00-09:00. En betydande del av alla singel-cykelolyckor skedde centralt i Karlstad. I de centrala delarna är det mycket folk och fordon i rörelse vilket antogs vara en anledning till de många olyckorna där. Flera broar i Karlstad var också relativt olycksbenägna. Majoriteten av olyckorna på/vid broarna var drift- och underhållsrelaterade, mer specifikt på grund av halka på is, snö och sand.

Nyckelord: Karlstad, cyklister, cykel-singelolyckor, cykelolyckor, STRADA, olycksorsaker, drift, underhåll, cykelväg, utformning.

Contents

Preface

In this study, the bicycle accidents in the city of Karlstad were compiled and analysed. The focus of the study was on single bicycle accidents. Bicycle accidents in Karlstad from January 2009 to December 2013 were included in the study. The project was carried out at the Department of Civil and Environmental Engineering, Division of GeoEngineering, Chalmers University of Technology and at the municipality of Karlstad.

During the work with the Master´s Thesis several persons have provided important knowledge and supported me through the work. Helpful discussions have been carried out with several persons to improvement my knowledge in the area.

I would like to thank my main supervisor Anders Markstedt for guiding me through the work and discuss proper approaches.

Further I would like to thank Ingemar Johansson and Sara Hesse at the municipality of Karlstad for the idea for this Master Thesis and their helpful discussions about the thesis.

I am also grateful to Magnus Berg and Therese Malmström at the Swedish Transport Agency for the god introduction course to STRADA and the interesting and educational discussions during the course.

Karlstad, June 2015

Karl Borgstrand

Notations

Expressions

Bicycle accident	An accident with at least one bicyclist injured that have occurred in a transport or traffic environment.
Bicycle path	A path that bicyclists are allowed to use. In the report, no distinction was made between separated bicycle paths and combined bicycle paths.
Bicycle trip	A bicycle trip is defined as a main travel where the bicycle has been the main transportation mode.
Institutional care	That a person have been admitted to the hospital for healthcare more than one day.
Maintenance	Measures to restore the characteristics of the road to the design envisaged for during construction or improvement. Increases the residual value of the road.
Main travel	If you bicycle daily to and home from work it is defined as two main travels. If you bicycle to the store to buy groceries and then home without stopping at a so-called main travel point, it is defined as one main travel.
Major bicycle path	In Karlstad's "bicycle map" over the bicycle paths there are eight paths that are more highlighted. These are in the report called the major bicycle paths. The bicycle path does not necessary be a separated bicycle path.
Multi-part accident	An accident where more than one road user have been involved.
Operation	Measures to keep the functional characteristics that the roads are designed for. It does not increase the residual value of the road.
Single bicycle accident	An accident where only one bicycle has been involved.

Abbreviations

AIS	Abbreviated Injury Scale
ASEK	Workgroup for social cost calculations and analyses in the transport sector – led by the Swedish Transport Administration
ISS	Injury Severity Score
GIS	Geographic information system
MSB	Swedish Civil Contingencies Agency
NTF	The national association for promotion of traffic safety in Sweden
NWT	Nya Wermlands-Tidningen – Regional newspaper

STRADA	Swedish Traffic Accident Data Acquisition
SvD	Svenska Dagbladet – National newspaper
VSL	The value of one statistical life
VTI	Swedish National Road and Transport Research Institute

1 Introduction

Karlstad is the largest municipality in Värmland and the 21st largest of Sweden's municipalities (Municipality of Karlstad, 2013). The municipality is located just north of lake Vänern and has around 87 000 inhabitants today. In 2009 around 66 000 of the population lived in the central parts of Karlstad and Skåre and in 2013 that population had increased to 69 000.

The municipality of Karlstad have the intention to be one of the leading municipalities in Sweden when it comes to bicycling and everything that concerns it (Municipality of Karlstad, 2015a). The municipality are going to invest in new bicycle paths and develop the existing bicycle paths to improve the environment for the bicyclist. In late November 2014, a local newspaper published numbers that indicated that the number of bicyclists in Karlstad has increased the last year (Sims, 2014).

An article published in Svenska Dagbladet (SvD) stated that many bicyclist is severe injured due to low quality on the bicycle paths in Sweden (Thurfjell, 2014). The bad quality of the bicycle paths was often a result of poor or improperly maintenance. The facts in the article came from a study performed by the Swedish Transport Administration. The study was a comparative study that analysed how sixty municipalities in Sweden maintains their bicycle path (Swedish Transport Administration, 2014a). The analysis was based on two main criteria, quality assurance and maintenance of the bicycle path. The maximum points that a municipality could get is 64 points, 20 points in the quality assurance criteria and 44 points in the maintenance criteria. The maintenance criteria is divided into three different sub criteria, maintenance during the winter months, removal of sand and maintenance during the snow free months. In the study, the municipality of Karlstad was in the bottom of the statistics of operation and maintenance of the municipality's bicycle paths.

In an attempt to improve the conditions for the bicyclists, the municipality of Karlstad are testing a new method to remove snow, better lightning, smoothen up sharp corners and perform safety increasing measures in narrow passages (Wik, 2014). To improve the conditions for bicyclist during the winter months, the municipality of Karlstad tried a new method for removal of the snow on some of their major bicycle paths the winter 2014/2015 (Metro Karlstad, 2015). The principle of the method is to use a vehicle with a power broom and a brine (solution with salt in water) spreader. The broom sweeps away the snow and the spreader distributes the brine onto the bicycle path. The municipality have set the demand that the snow clearance will start when two centimetres of snow have fallen instead of the previous four centimetres. In the ideal case there will be no snow left after execution of the snow clearance method. This results in that there is no need for grit on the bicycle path where the method is used.

In Sweden, more bicyclists then car users are involved in severe accidents (Lindberg, 2014). The most common type of accident for bicyclist are single accidents is concluded in several studies. The single accidents are often a result of poor or improperly maintenance of the bicycle paths (Swedish Transport Administration, 2014b). It is around 70-80% of all accidents that are single bicycle accidents. The article stated that of the single accident 44% occur due to poor or improperly maintenance. According to Niska (Niska et al., 2013), around 30% of the accidents relates to poor or improperly operation or maintenance. The two numbers differs but are in the same range.

1.1 Aim

The aim with this MSc-thesis was to perform a study of the bicycle accidents in Karlstad to see why, how and when bicycle accidents occur, with focus on the single accidents. The study aims to increase the knowledge about bicycle accidents, especially single bicycle accidents in a midsize city. This so the traffic safety for bicyclists can be increased in the future.

1.2 Limitations

The literature study was concerning bicycle accidents in Sweden. The study of different measures to increase the traffic safety for bicyclists was limited to measures that were common in Sweden or countries with similar weather conditions.

As the source for the statistics, STRADA (Swedish Traffic Accident Data Acquisition) was used. STRADA includes data from the police and the emergency hospitals over accidents for pedestrians, car users and bicyclists in the traffic environment. The data from STRADA might not completely correspond to the actual situation. This because it can be a number of unreported accidents due to minor accidents that neither the police nor the hospitals knows about or inaccuracies in the reports. The reported accidents from the emergency hospital in Karlstad were deficient from 2014 to today due to shortage of staff (Berg, 2015). The police have had problems with their registration during 2014 so the statistics from the police is also deficient for 2014 (Rabe, 2015). Due to this, the accidents included in the report had to occur from January 2009 to December 2013.

The area included in the study was limited to the central parts of the municipality of Karlstad, which includes the city of Karlstad and Skåre. This was the geographical boundary in STRADA when gathering the statistics over the bicycle accidents.

Statistics over all type of bicycle accidents in the city of Karlstad were gathered. Statistics over all bicycle accidents showed the percentage of all accidents that the single bicycle accidents stood for. However, as mentioned before the analysis focused on the single accidents.

1.3 Methodology

The project began with a literature study about characteristics of bicycle accidents in Sweden. The study included why, how and where bicycle accidents occur in Sweden in general. Different preventive measures that were common to increase the traffic safety for the bicyclists were also included in the study. The literature study was a review of existing technical and scientific literature, especially from the Swedish Transport Administration, MSB and VTI.

The number of bicyclists in Karlstad and the distribution during the year and day were estimated from statistics provided by the municipality of Karlstad. This were done in order to use the bicycle distributions in the analysis of the accident statistics. The municipality had six monitoring stations in the city to monitor the number of bicyclists. Unfortunately, indications of that the monitoring stations have had periods when the stations have malfunctioned were found in the statistics. To get realistic values, the number of passing bicyclists during those periods were estimated with taking into consideration both the day and week of the malfunction. Days with malfunction were given the mean value of the same weekday the week before and after and also the day before and after the same week. The mean was thus effected on four different days. The estimation was performed in Excel because the estimation was in some cases an iterative process.

The work then continued with a compilation of the bicycle accident that had occurred in the city of Karlstad or Skåre. STRADA (Swedish Traffic Accident Data Acquisition) was the main source when the data were gathered. Statistics over all type of bicycle accidents in the city of Karlstad were gathered but the focus of the analysis was on the single bicycle accidents. More about the work process concerning STRADA can be found in Chapter 3, and in particular Section 3.5.

The analysis of the results was a quantitative analysis based on the compilation of the data from STRADA. The analysis included studying areas that were prone to accidents, which age range that were involved in most accidents, in what time on the day and year most accidents occurred and common accidents causes. The bicycle accidents were dived into six different accident types that have been used in similar studies; single bicycle accidents, bicycle-car/truck accidents, bicycle-bicycle accidents, bicycle-moped accidents, bicycle-pedestrians accidents and other/unknown accidents.

The causes of the single bicycle accidents could be several and due to that, six main classifications were used for describing the causes. These classifications were operation and maintenance, bicycle path design, state and behaviour of the bicyclist, the bicyclist in interaction with the bicycle, the bicyclist in interaction with other road users and accidents with an unknown cause. The division into six classifications simplified the analysis due to the fever accident causes. For some classifications there were appropriate to do a sub-division to get a more detailed description of the accident causes. The classifications used in this report were inspired by the report "Single bicycle accidents – Analyse of accident data and interviews" (Niska et al., 2013).

Example of causes that were included in each classification are show below. Examples were given in order to clarify the six main classifications.

- Examples of *Operation and maintenance* related accidents are slipperiness due to snow/ice/gravel/leafs or unevenness/holes.
- Examples of *Design of bicycle paths* related accidents are accidents due to poor lightning of the bicycle path, sharp corners or high curbs.
- Examples of *State and behaviour of the bicyclist* related accidents are influence of alcohol, high velocities or carelessness by the bicyclist.
- Examples of *The bicyclist in interaction with the bicycle* related accident are malfunction of the bicycle (broken chain, object in the wheel etc.), transport of objects or when the bicyclist steps on or off the bicycle.
- Examples of *Interaction with other road users* related accidents are when the bicyclist need to swerve due to pedestrians on the bicycle path or for other road users.

As mentioned before, the accident causes can be several. When classifying the accidents, the judged main cause for the accidents was the basis for the classification.

When identifying locations with high concentrations of accidents two different methods were used. When identifying locations with high concentrations of accidents, a GIS based software (QGIS) was used.

In the first method, a map over the intensity of the accidents was made through an analysis of the accidents in GIS. The analysis was performed with help of a built-in function in GIS that was called *Intensity map*. The intensity of the accidents is dependent on both how many accidents that were within the chosen distance and how close they were to each other.

When identifying locations with high concentrations of accidents outside the central parts of Karlstad one more analysis in GIS was performed. The analysis was performed with buffer zones to see in which areas it have happened five or more accidents within a radius of 100m of each other. This was done in order to decrease the importance of the distance between the accidents compared to the previous analysis. This due to that several accident locations are relative uncertain and in the intensity analysis the intensity was higher the closer to each other the accidents have occurred. If two accidents mistakenly was placed right next to each other, the intensity became unreasonable high.

To see variations during the day, the single bicycle accidents from 2009-2013 were separated over the time of the day. From the statistics a mean for each hour were calculated and the time of occurrence was set to the middle of each hour. For example, for accidents that occurred between 02:00-03:00 the time of occurrence was set to 02:30.

An analysis in Excel was performed to see which hour of the day that had the highest probability for a single bicycle accident. The number of bicyclists were compared to the number of accidents for each hour. The probability for an accident was not so interesting to present because the number of bicyclists were relative uncertain. The basis probability was set to highest probability among the hours. Each hours' probability was compared to the maximum probability to see relations between different hours. The same thing was also performed for the months of the year to see which month that had the highest probability for a single bicycle accident.

An analysis in GIS was performed to see how many accidents that have occurred on one of the major bicycle paths in Karlstad. The analysis was performed with help of a buffer zone around the major bicycle paths and all accidents within that zone was included in the analysis of the accidents on the bicycle paths.

2 Literature Study Concerning Bicycling in Sweden

A literature study was performed in order to get a background knowledge about bicycle accidents and bicycling in Sweden. The literature study included an introduction of bicycle traffic in Sweden and Karlstad, a general description of bicycle accidents in Sweden, measures to reduce the number of bicycle accidents and costs for the society due to bicycle accidents.

2.1 Bicycling in Sweden

Bicycling in Sweden was very common in the 1930s but then it decreased significantly. For a long time, the bicyclist where an under-prioritized. However, in the 1990s a change in attitude led to that many municipalities in Sweden started to invest in improvement measures for bicyclists (MSB, 2013). Bicycling results in less emission, which improves the environment in general but also the local environment in the cities (Robertson, et al., 2013). In Sweden today, many municipalities works for a better local environment to improve the environment in the city. Today, both environmental issues and public health is two important subjects for decision-making authorities.

In Sweden the bicycle was used as the main mode of travel for 9.2% from 2011-2012 and the percentage have been relative constant for the last years (Spolander, 2013). An average trip with the bicycle as a main mode of travel was around 4km. The car was still the main transportation mode in Sweden. The car was used as the main mode in 54.5% of all travels.

In the Swedish national travel survey performed by Trafikanlys, it was stated that a person in average make 1.62 main travels each day (Wiklund, 2012). A main travel is to some extent a difficult to understand concept. Wiklund explains a main travel in the following way: “If you bicycle daily to and home from work it is defined as two main travels. If you bicycle to the store to buy groceries and then home without stopping at a so-called main travel point, it is defined as one main travel”.

2.2 Bicycling in Karlstad

The chapter describes the bicycle traffic in Karlstad. It includes estimations of the bicycle flow in Karlstad over the year, week and day and brief information about the helmet use for bicyclists. The information in this chapter was later used in the analyses and the discussion.

2.2.1 Bicycle flow over the year, week and day

In a report over the usage of the bicycle as a main mode of travel, Karlstad places themselves quite high in the ranking (Spolander, 2013). In Karlstad, 16% of the transportation of people was made with the bicycle in 2011-2012. In a recently survey over the travel habits in Karlstad, that number was increased. Today, the citizens used a bicycle as the main transportation mode in 21% of the travels (Stålner, et al., 2015).

The bicycle trend in Sweden today was hard to assess due to there were conflicting analyses according to MSB. An estimation of the flow in Karlstad was performed to see variations in the bicycle flow.

The municipality of Karlstad had six monitoring stations placed around the city to monitor the number of bicyclists (Municipality of Karlstad, 2015b). The two oldest monitoring stations were installed during 2010 and monitor the bicycle traffic on Sandbäcksgatan and by Sandgrund. These two were located along two of the major bicycle paths in the city as can be seen in the figure below. The black lines are the major bicycle paths in Karlstad and the two red dots are the placement of the two monitoring stations.

Figure 1 – The figure shows the placement of the monitoring station at Sandbäcksgatan (the left red dot) and by Sandgrund (the right red dot). The black lines are the major bicycle paths in Karlstad and the two red dots are the placement of the two monitoring stations.

Indications of that the monitoring stations have had periods when the stations malfunctioned were found in the data over the flows. To get realistic values, the number of passing bicyclists during those periods were estimated with taking into consideration both the day and week of the malfunction. The values for the periods of malfunction was a mean of the weekday the week before/after and the weekday before and after the malfunction.

The estimation was an iterative method because the monitoring stations could have malfunctioned for a long period. Due to this, Excel was used during the estimation. A graph over the estimated number of passing bicyclists each year can be seen in the graph below.

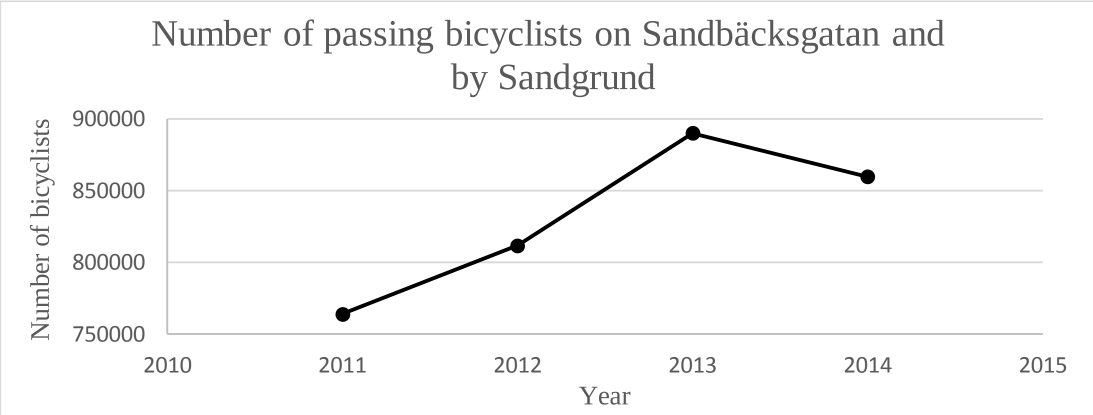

Figure 2 – The graph shows the estimated number of passing bicyclist on Sandbäcksgatan and by Sandgrund from 2011-2014. The statistics were modified due to malfunction of the two monitoring stations.

The modified data from the two monitoring stations shows that the bicycle flow on the two bicycle paths had increased from around 764 000 bicyclists in 2011 to 860 000 in 2014. However, it was seen that the bicyclists had decreased with approximately 30 000 bicyclists from 2013 to 2014. This result conflicts with the numbers that the local newspaper presented, but as mentioned before the data was modified in this report. It was seen that the number of bicyclists on Sandbäcksgatan had increased while the traffic by Sandgrund had decreased.

The modified data from the monitoring stations were used to see variations during the year on Sandbäcksgatan and by Sandgrund. The distribution over the years from 2011 to 2014 are shown in the bar chart below.

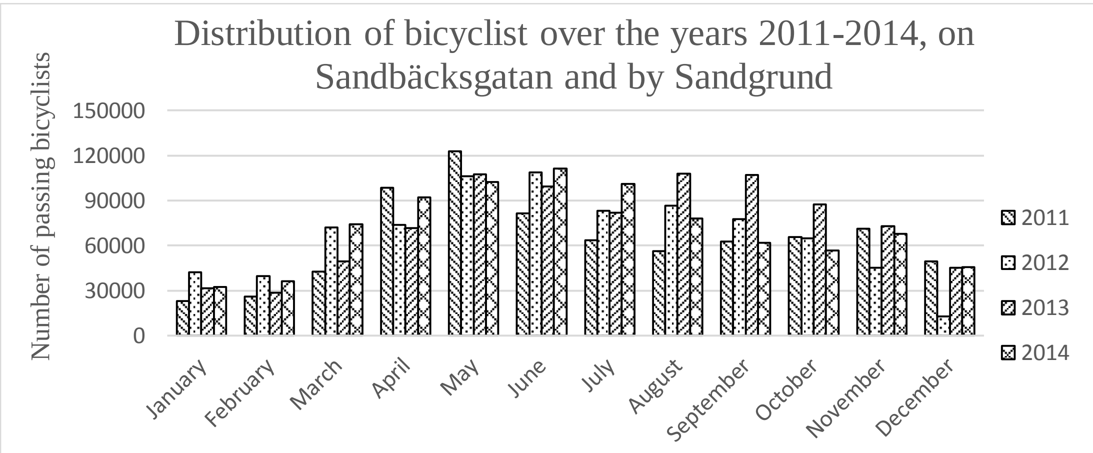

Figure 3 – The bar chart shows the distribution of bicyclist for the years 2011-2014, on Sandbäcksgatan and by Sandgrund. The distribution for each year from 2011-2014 was presented separately to see variations from year to year.

The modified data shows that the number of bicyclists were highest during the summer months May and June. It was also seen that it was a relative high number of bicyclist during the late part of the summer and the early autumn, especially during 2013.

The modified data from the monitoring stations were used to see variations during an average week on Sandbäcksgatan and by Sandgrund. The distribution of bicyclists over an average week, for the combined flow on Sandbäcksgatan and by Sandgrund for the years 2011 to 2014, is shown in the bar chart below. The distribution was expressed as the percentage of bicyclists per day of the total number of bicyclists.

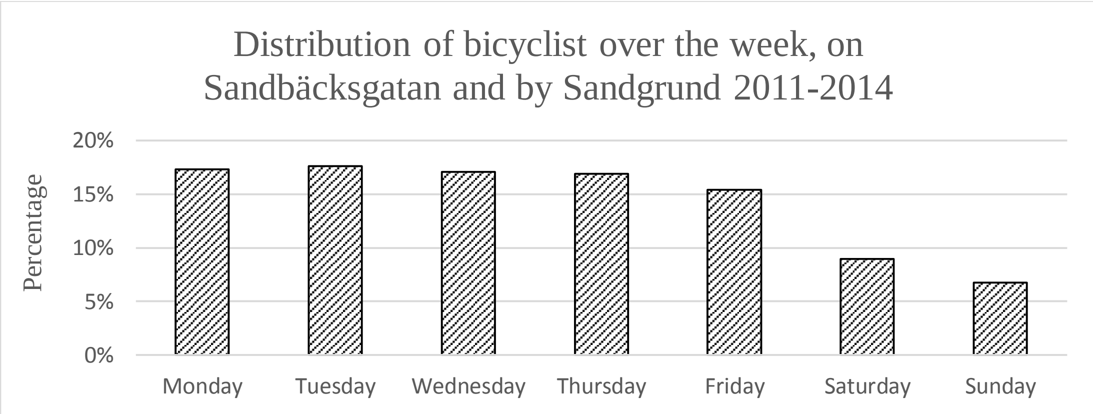

Figure 4 – The bar chart shows the distribution of bicyclists over the week on Sandbäcksgatan and by Sandgrund from 2011 to 2014. The distribution was expressed as the percentage of bicyclists per day of the total number of bicyclists.

The modified data shows that the number of bicyclists were highest during the weekdays, Monday to Friday. The percentage of bicyclists were quite steady around 17% for the weekdays but were lower than 10% for the weekends.

The data from the monitoring stations were used to see variations during an average day on Sandbäcksgatan and by Sandgrund. The statistics were used without any modifications of the values. The modification was not performed because it was extremely time demanding and it was judged that the periods with malfunction station would not affect the distribution over the day significantly. The distribution for the combined flow on Sandbäcksgatan and by Sandgrund from 2011 to 2014 is shown in the graph below. The distribution was expressed as the percentage of bicyclists per hour of the total number of bicyclists.

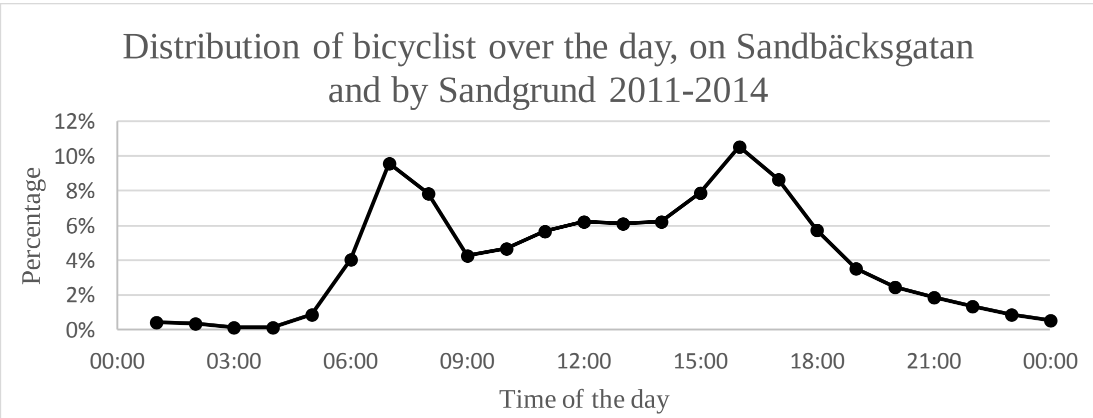

Figure 5 – The graph shows the distribution of bicyclists on Sandbäcksgatan and by Sandgrund from 2011 to 2014. The distribution was expressed as the percentage of bicyclists per hour of the total number of bicyclists.

The bicycle flow for the two locations had similar distribution and due to that, the flows for the two locations were combined. The highest number of bicyclists were around 06:00-08:00 and 15:00-18:00. The lowest number of bicyclists were at the night around 00:00-04:00. The distribution of the bicyclists were similar to the distribution of car-traffic during weekdays, which also has a peak on the morning and in the afternoon (Lannér, 2012).

2.2.2 Use of helmet

The national association for promotion of traffic safety in Sweden performed an analysis in the spring of 2014 to see the number of bicyclists that used helmet in Karlstad (Bergström, 2015). The analysis was performed along three of the major bicycle paths in Karlstad. It was seen in the analysis that around 28% of all bicyclists used a helmet during the analysed period. It was more common that men used a helmet than women.

2.3 Bicycle accidents in Sweden

There has been a positive trend in Sweden when it comes to bicycle accidents with fatal outcome in Sweden since 1987. The number of persons that are fatal injured have decreased significant since 1987 according to a study performed by MSB (MSB, 2013). The study had similar results as a study performed by VTI in 2013, which strengthens the results (Niska, et al., 2013). Around 70 bicyclists died in traffic the year 1987. In 2011, it was just below 20 bicyclists that died in traffic. From 2009 to 2011, the number of fatal injured bicyclists were around 20 persons. In a press release from NTF (the national association for promotion of traffic safety in Sweden) during 2014, the positive trend had turned to a negative trend (NTF, 2014). The press release stated that the number of pedestrians and bicyclist that got severe injured had increased during the first part of 2014. No analysis of bicycle accidents from the year of 2014 was found during the completions of this report.

When it came to the injuries due to bicycle accidents, studies often distinguishes between outpatient care and institutional care. Outpatient care means that the patient don’t need to be admitted for longer than 24 hours and institutional care means that the patient needs to be admitted longer than 24 hours. The study from MSB indicated that there was a negative trend involving the number of bicyclists that needed institutional care in Sweden. The numbers of bicyclists that needed institutional care had slightly increased since 1987 to 2011 (MSB, 2013). Around 290 bicyclists per 100 000 inhabitants needed institutional care during 2011 in Värmland. The number of bicyclists that needed institutional care stood for around one third of all road users that needs institutional care. The car users stood for another third of the need of institutional care. Those two groups were the dominating groups when it came to need of institutional care of road users.

Another way to express the number of injured bicyclists was seen in a report by Spolander 2014 (Spolander, 2014). The number of injured bicyclists were expressed as number of injured per million bicycle trips. A bicycle trip was defined as a main travel where the bicycle had been the main transportation mode.

The number of injured bicyclists that had been involved in a single bicycle accident were mentioned in the report. The number of injured bicyclists were expressed as number of injured per million bicycle trips. The number of injured in the report varied from around 8-43 per million bicycle trips, with a mean just over 18.3 (Spolander, 2014). Karlstad placed themselves in the middle of the study with around 20 single bicycle accidents per million bicycle trips.

The number of injured bicyclists that had been involved in a multi-part accident were also mentioned in the report. The number of injured bicyclists were expressed as number of injured per million bicycle trips. The number of injured varied from around 2.5-11 accidents per million bicycle trip, with a mean about 4.5 (Spolander, 2014). Karlstad placed themselves in the top with about 2.5 multi-part accidents per million bicycle trips.

In the report by Spolander 2014, Spolander saw a connection between the percentage of the bicycle travel and the number of injured bicyclists. The higher usage of the bicycle as a transportation mode resulted in less accidents. Spolander believes that the connection was related to that the higher number of bicyclists the better infrastructure for the bicyclists. A higher number of bicyclists can also increase the awareness of the car drivers in a city, which may increase the safety for the bicyclists. However, more bicyclists results in more crowded bicycle paths/areas for the bicyclists, which can decrease the traffic safety for the bicyclists.

A part of the study from MSB was to analyse data from 2007-2011 to see which age range that had the highest probability to be involved in a severe bicycle accident (MSB, 2013). It was seen that the age range 0-14 was overrepresented, especially men, and it was also relative common with elderly persons that was severe injured. The group that had the highest probability for a fatal accident was men older than 65 year. It was more common for men to die in a bicycle accident compared with women.

2.3.1 Common causes for bicycle accidents

Several factors affects bicycle accidents and the accident causes can often be a combination of different factors (Nilson, et al., 2013). Human aspects, the surrounding environment and the technology can all effect the accident cause of bicycle accidents. An illustration of how the human aspects, the surroundings and the technology can interact to cause accidents is shown below.

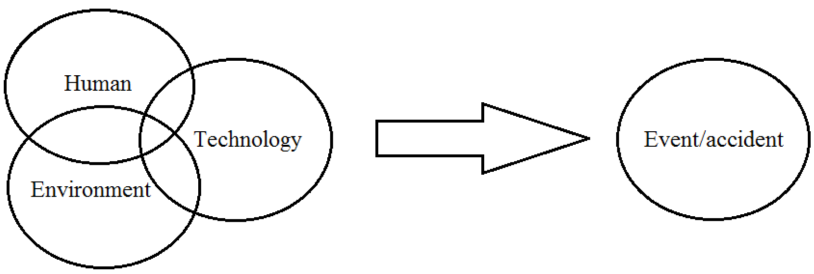

Figure 6 – The figure shows how different factors can interact as a cause for bicycle accidents.

There was relative much research performed regarding bicycle accidents. The research agrees on that the most common type of bicycle accident, without a doubt, were single bicycle accidents. However, the percentage between the different accident types slightly varied from research to research but the magnitude was the same.

The graph below shows the distribution between different accident types for bicyclists, which needed emergency hospital attendance, based on data from 2009-2010 (MSB, 2013).

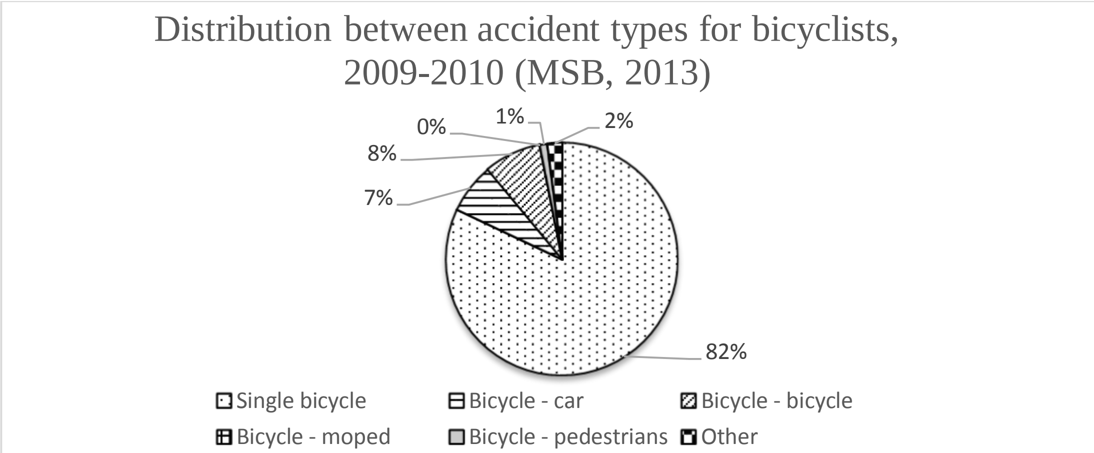

Figure 7 – The figure shows the distribution between different bicycle accident types between 2009-2010 (MSB, 2013). The most common type, by far, were the single bicycle accidents.

As can be seen in the figure above, single bicycle accidents were the most common bicycle accident type followed by accidents between bicyclists and cars. The percentage that single bicycle accidents stood for were around 70-80%. The accidents between bicycles and cars were slightly higher in other reports/research compared to the values seen in the figure above. For example in an analysis performed by the University of Karlstad in 2013, around 10-14% of the accidents were between bicycles and cars (Nilson, et al., 2013).

Several factors affects single bicycle accidents, influencing both the bicycling and the behaviour of the bicyclists. Due to this, the causes of single bicycle accidents can be several and sometimes combination of several causes.

As mentioned in the methodology, six main classifications were chosen for the accident causes of the bicycle accidents. The table below shows the distribution of the accident causes for single bicycle accidents where the bicyclist is severely injured (ISS 9+) in Sweden from 2007-2011. This were the results from an analysis of single bicycle accidents made by VTI in 2013 (Niska, et al., 2013).

Table 1 – The table shows the percentage for different main causes for severe single bicycle accidents for 2007-2011 (Niska, et al., 2013). This were the results from an analysis of single bicycle accidents made by VTI in 2013. Six main accident cause classifications were used, as can be seen in the table.

Main cause for accidents where the bicyclist have been severely injured	**Percentage**
Operation and maintenance	17 %
Design of bicycle paths	12 %
State and behaviour of the bicyclist	9 %
The bicyclist in interaction with the bicycle	17 %
The bicyclist in interaction with other road users	6 %
Unknown	39 %

The main causes for single bicycle accidents were accidents with unknown accident cause. For the causes that were known the operation and maintenance and the bicyclist in interaction with the bicycle were the most common accident causes. Those two classifications together stood for almost half of all the single bicycle accidents. The results from VTI were similar to the results from a study by MSB 2013.

A recent article in NWT, the local newspaper in Värmland, stated that the operation and maintenance of the bicycle paths were the most common cause for single bicycle accidents where the bicyclist suffered from incapacitating injuries in Sweden (Thurfjell, 2014). The article mentioned that operation and maintenance caused around 44% of the accidents with incapacitating injuries. The results that the article were based on also originated from a report by VTI. The included accidents in the analysis were accidents where the bicyclist was judged to sustain a future medical disability on 1% due to the accidents (Niska & Eriksson, 2013).

In VTI:s report, concerning single bicycle accidents where the bicyclists where severely injured (ISS 9+), they presented a more detailed analyse of the accident causes (Niska, et al., 2013). A short description of the most interesting finding is presented below.

The majority of the maintenance and operation related accidents were often due to slipperiness (Niska, et al., 2013). Snow or ice on the bicycle paths was often the cause for the slipperiness accidents. Loose sand also caused slipperiness in many cases. Loose sand was often a problem at the spring because the sand was used during the winter months as a measure for better friction on roads. The sand was then not removed in time on the spring, resulting in accidents. Other common causes were uneven surfaces and that the bicyclists have run into something.

Bicycle path design related accidents were often a result of that the bicyclist have run into something that has to do with the design, for example, curbs/pavement edges (Niska, et al., 2013). The velocities of the bicyclist and if there were any sharp corners often affected these types of accidents. Poor lightning of bicycle path was also a quite common accident cause.

Accidents related to the state and behaviour of the cyclist were often a result of that bicyclist had lost control of their bicycle (Niska, et al., 2013). Which factors that had led to the lost control were often hard to say but it could for example be, high velocities, alcohol and so on. A survey performed by the consultants company Tyréns indicated that high velocities and unfocused bicyclists mainly were the causes for state and behaviour related accidents (Tyréns AB, 2013).

The bicyclist in interaction with the bicycle related accidents were often accidents when the bicyclist stepped on and off the bicycle (Niska, et al., 2013). Around half of all accidents were a result of this and it was often older persons that were involved in step on and off related of accidents. Other common causes were malfunction of the bicycle, improper use of the brakes and objects that were stuck in the wheels.

The bicyclist in interaction with other road user related accidents were mainly accidents when the bicyclist needed to swerve because of other road users (Niska, et al., 2013). In some cases, the bicyclists needed to swerve due to animals on the road.

2.4 Measures to Reduce the Number of Bicycle Accidents

There are several measures to improve the safety and the conditions for bicyclists. One way can be to start from the accident causes for bicycle accidents and see which measures that are suitable for each cause. Common causes for bicycle accidents in Sweden were described in Chapter 2, and in particular Section 2.3. The measures have been divided into three sections for a better overview of the different measures. The three sections are well-designed areas/paths for bicyclists, suitable summer maintenance and suitable winter maintenance.

2.4.1 Well-designed areas/paths for bicyclists

As was mentioned in Chapter 2, and in particular Section 2.3, a part of the bicycle accidents were a direct result of poorly designed areas or paths for bicyclists. Poorly designed bicycle paths might lead to bicycle accidents that is indirect caused by the design (Niska, et al., 2013). For example, accidents when the bicyclists swerves for other road user may be a result of poor design such as a to narrow bicycle path. Due to that, well-designed areas or paths for bicyclists is a good measure to increase the traffic safety.

Well-designed areas or path can be areas where bicyclists and other road users are separated so the number of conflicts decreases. It can also be bicycle paths with smooth curves, good lightning and a good visibility over the area (Niska, et al., 2013). Another important aspect in a good design is to have good clarity so the bicyclists know where to bicycle and not, the same applies for the other road users. This might also decrease the number of conflicts between bicyclists and other road users.

2.4.2 Suitable operation and maintenance during the summer

As was mentioned in Chapter 2, and in particular Section 2.3, a part of the bicycle accidents were a direct result of poorly maintenance and operation during the summer months. With a suitable maintenance during the summer, accidents that were caused poor operation and maintenance can be reduced. It is mainly the accidents caused by loose sand, other objects on the bicycle path or uneven surfaces that can be reduced through a proper operation and maintenance during the summer. Proper operation and maintenance increases also the life length of the bicycle path and maintains the value of the road (Lannér, 2014).

Suitable summer maintenance can involve more frequently sweeping to remove objects, sand and leafs on the roads/paths, repairing potholes, new coating of the road and good sight clearance.

2.4.3 Suitable operation and maintenance during the winter

As was mentioned in Chapter 2, and in particular Section 2.3, a part of the bicycle accidents were a direct result of poorly operation and maintenance during the winter. With a suitable operation and maintenance during the winter, the number of accidents caused by slipperiness could be reduced. Slipperiness caused a large part of the single bicycle accidents during the winter.

Suitable winter operation and maintenance can involve a well-functioning snow removal method and a suitable interval for the maintenance. The winter maintenance should result in an even surface with good friction. There are several methods for snow and ice removal available. The most traditional method is to remove the snow with ploughing and then spread a material afterwards to enhance the friction (Niska, 2011). There are different materials available but the most common ones are sand, gravel and in some cases stone chippings. Some relative new winter maintenance methods are spreading hot sand, ice ripping/pressing patterns on the ice or sweeping away the snow and spread brine afterwards. These methods exists in Sweden but are not commonly used in full scale (Niska, 2011).

Another important part of winter maintenance is to keep a good sight for the cars and bicyclists (Niska, 2011). Large snowbanks due to too large amounts of snow might be a problem for the visibility for the road users resulting in dangerous situations. With well-planned storage areas for the snow in urban these kinds of problems can be reduced.

2.5 Cost for the society due to bicycle accidents

Bicycling leads to several indirect winnings for the society. It is winnings in terms of better public health and a better environment, both the local - and international environment. Bicycle accidents often results in several costs that is not so often recognized. Accidents can result in high costs for the society. Example of this are costs for healthcare, loss of production, damage to property, police and insurance costs and so on (Bäckmark, 2002).

To compare winnings and costs for the society due to bicycling, the non-monetary costs and winnings are given a monetary value. It is very hard to put non-monetary values on several of the effects of bicycling. Effects on the public health, the environment and fatalities are examples that are examples of effects that are very hard to set monetary values on.

The Swedish Transport Administration have put together a workgroup that are responsible for principles and calculation values in the transport sector. The workgroup is called ASEK (Swedish Transport Administration, 2014c). ASEK uses a term “VSL” for the benefit loss for the society due to a fatality. This term is used when estimating the cost for the society due to bicycle accidents. In a report provided by ASEK recommended cost for the society for an injured bicyclist are given (Swedish Transport Administration, 2014d). The average costs for the society for an injured bicyclist were estimated by ASEK and can be seen below:

- 1 000 000 SEK in a short term analysis and,
- 0.8 MSEK * discount factor + 0.2MSEK in a long term analysis

The values above were an average cost for an injured bicyclist in Sweden, including all effects, in monetary values, of the accidents. The values above were for the price level in 2010.

3 Description of STRADA

This chapter aims to give the reader a short description of STRADA. The chapter includes an introduction to STRADA, information about the confidentiality, how the degree of the injuries are described in STRADA, routines for the emergency hospital in Karlstad and the work procedure during the collection of data about the bicycle accidents in Karlstad.

3.1 Introduction to STRADA

STRADA stands for Swedish Traffic Accident Data Acquisition and is a national information system for accidents and injuries in the transport sector (Berg & Malmström, 2015). The Swedish Transport Agency is responsible for administration of the information in STRADA.

The information comes from two sources, the police and the emergency hospitals (Berg & Malmström, 2015). The emergency hospitals are not obligated to report accidents to STRADA, but if they do, they are compensated for it. The hospitals needs an approval from the patient to register the accident in STRADA. Today are 98% of all hospitals reporting accidents to STRADA. The hospital in Karlstad started to report to STRADA 2001. Due to shortage of staff, the reported accidents from the hospital in Karlstad were deficient for 2014 and 2015 (Berg, 2015).

Unlike the hospitals, the police is obligated to report all accidents that are classified as a road traffic accident in which a person have been injured. A road traffic accident is defined as an accident on a road where at least one vehicle was involved. The definition of a road and a vehicle is important to have knowledge about so the user of STRADA is aware of which type of accidents that are and not are reported by the police. The definition of a road must fulfil one of three criteria (The Committee on Industry and Trade, 2001a):

1. “A road, street, square or other type of way and areas that it is regular used for traffic with motor vehicles”
2. “A way designed for bicycle traffic”
3. “A walkway or a riding track beside a road as defined in either 1 or 2”

A vehicle is defined as “A device on wheels, tracks, skids or similar which is constructed mainly for traveling on the ground but not on rails. Vehicles are divided into motorized vehicles, trailers, sidecars, bicycles, horse-drawn vehicles and other vehicles” (The Committe on Industry and Trade, 2001b). In other words, trams are not defined as vehicles according to the Swedish law.

That the information about accidents comes from both the emergency hospitals and the police often results in that the same accidents are reported by both instances. Because of this, STRADA have a matching function that combines the information from both the hospitals and the police whenever there is information about the same accident (Berg & Malmström, 2015). The information from the hospitals and the police are complements to each other’s information.

Although both the emergency hospitals and the police reports to STRADA there are still an unknown number of unreported cases (Berg & Malmström, 2015). Examples of unreported cases are cases where there only are material damages, minor accidents that neither the police nor the hospitals knows about, inaccuracies in the reports, cases there the patient declines to be reported or that the reporting procedures fails. There was problem with the reporting from the police during 2014, which may result in that the number of reported accident from the police are deficient for 2014 (Berg, 2015). However, the number of unreported cases since the start of STRADA have been reduced. This because in the beginning only the police reported accidents and not the emergency hospitals, which resulted in many unreported accidents, especially for unprotected road users.

It can be a delay between the occurrence of accidents and the date that they are reported to STRADA (Berg & Malmström, 2015). The police have to report road traffic accidents within 7 days except for fatal accidents when it is 5 days. The emergency hospitals do not have any requirements for when they should report accidents, but the Swedish Transport Agency recommend them to report within 45 days from the occurrence of the accidents.

The de-identified information in STRADA can be accessed through a STRADA withdrawal web that are available for authorized people. The information is compiled into a statistical report in excel. In the statistical report there are information about the accidents such as, location, time, road conditions and so on. More about the de-identified information in next section 3.2.

3.2 Confidentiality

The database STRADA contains information about individuals and includes hospital records and police reports. The law "Personal Data Act" and "the public access to information and Secrecy act" governs STRADA to ensure that information about individuals are confidential (Berg & Malmström, 2015). Due to this, the database is build up so the information from the emergency hospitals and the police are matched and then some of the information about the accidents are de-identified. Examples of information that are de-identified are personal ID, name and registration numbers. The users of STRADA withdrawal web only have access to the de-identified database.

The information from STRADA can be linked together with other information to identify individuals in accidents and with that find personal record from the hospitals and police reports for individuals (Berg & Malmström, 2015). Due to this, all STRADA users needs to sign a confidentiality agreement so information from STRADA are handled and used in a correct way.

3.3 Degree of injuries

The reports from the emergency hospitals uses AIS (Abbreviated Injury Scale) and ISS (Injury Severity Score) to describe the degree of the injuries (Berg & Malmström, 2015). AIS is a medical classification of the severity of each injury. AIS is graded from 1-6 where one is a minor injury and six is a maximal injury. ISS is the sum of all injuries that a person incurs. When calculating ISS, AIS is squared and the highest AIS for each region of the body is noted. ISS is then the sum of the three highest values of AIS. An uninjured person has an ISS of zero, a minor/moderate injury has an ISS of 1-8 and a severe injury has an ISS higher than nine.

If the persons have been hospitalised or not is noted in the hospital report (Berg & Malmström, 2015). If the person have been hospitalised it is also stated for how long that patient needed hospital care.

3.4 Routines for Karlstad´s emergency hospital

The emergency hospital in Karlstad have been registered accidents to STRADA since October 2001 (The Swedish Transport Agency, 2015). The hospital use the same routines as the rest of the emergency hospitals that register accidents to STRADA in Sweden (Unefäldt, 2015). The routine is that every person, that have been involved in an accident in a traffic environment comes to the hospital, are given a form that should be filled in. The form includes questions about the location, the cause and much more about the accident. The form are collected of a STRADA-registrar on the hospital are responsible for the registration the information in STRADA. The information about the accidents is complemented with additional information from the patients' medical records.

Before the information are registered to STRADA, the patients are controlled with another system to see that all patients have been given a form to fill in (Unefäldt, 2015). If a patients did not get any form to fill in, a form is sent home to the patient. Urban estimated the loss of registered patients to around 20% of all injured in the traffic environment that visits the hospital.

The emergency hospital have not changed their registration routines during the period that was studied, 2009-2013. However, as mentioned before, the reported statistics from the hospital in Karlstad is deficient from 2014 to today due to shortage of staff (Berg, 2015).

3.5 Work procedure

The first step of the withdrawal of data from STRADA was to define the time and the area. As mentioned before, the time was set from 2009-01-01 to 2013-12-31 and the area was drawn so it covered the central parts of the city of Karlstad including Skåre.

A search of all bicycle related accidents in Karlstad was done to get the distribution between different types of bicycle related accidents. A manual check of the accidents was done to check so there was not any accidents that was incorrect in any way. If any incorrect accidents were found then they were manually removed because they should not be included in the withdrawal. After that, a statistical report was created, including useful information about the accidents.

The results for the bicycle accidents in the central parts of Karlstad that were presented in Chapter 4 are based on the statistical reports from STRADA.

4 Result - Bicycle Accidents in Karlstad

This chapter presents the results over the bicycle accident situation in Karlstad and the chapter was based on the statistical reports from STRADA that was mentioned in Chapter 3. It is important to remember that it is only the bicycle accidents that were reported by the police or the emergency hospital that were included in the results. The statistical reports from STRADA included information of the bicycle accidents from 2009 to 2013. The result chapter includes the number of bicycle accidents, what type of accidents, the severity of the accidents and the variation during the year, month and day.

4.1 Bicycle accidents in general

In Karlstad, it had occurred 722 bicycle accidents during the studied period 2009-2013. In the figure below the location of all bicycle accidents from 2009-2013 can be seen. Every red or blue dot is one bicycle accident and the thin black line was the boundary for the central parts of Karlstad. The emergency hospital have reported the red dots while the police have reported the blue dots.

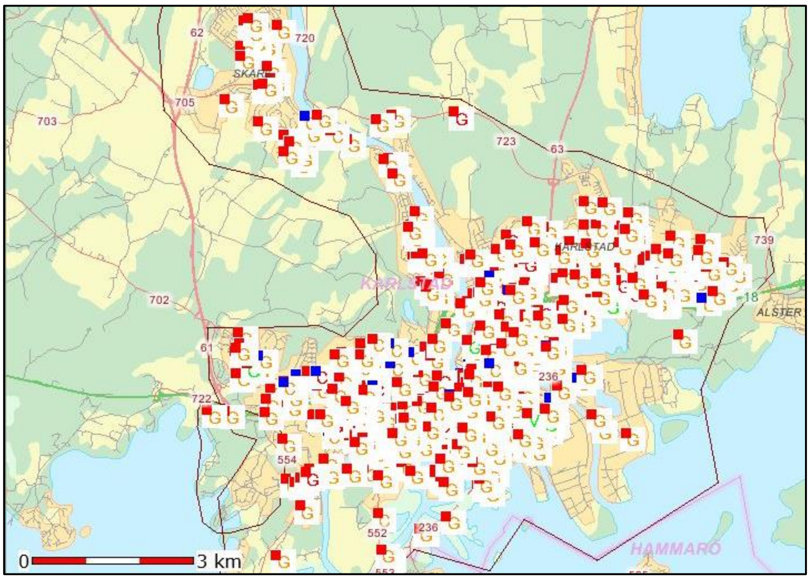

Figure 8 – The figure was generated in STRADA withdrawal web. It shows the location of every bicycle related accident from 2009-2013 in Karlstad. Every red or blue dot is a bicycle related accident. The emergency hospital have reported the red dots while the police have reported the blue dots. The black line in the figure was the limitations for the area that are included in the withdrawal.

For a part of the accidents, it was notified that the location of the accident is uncertain. Around 23% of the accidents in the figure have an uncertain location. However, through a manual review of the accident locations for the accidents with an uncertain location it was seen that the majority of the accidents had in most cases stated a street name or/and a district as the location of the accident.

The number of bicycle accidents in Karlstad was around 180 accidents during 2013 and the accident statistics during 2009-2013 can be seen in the graph below.

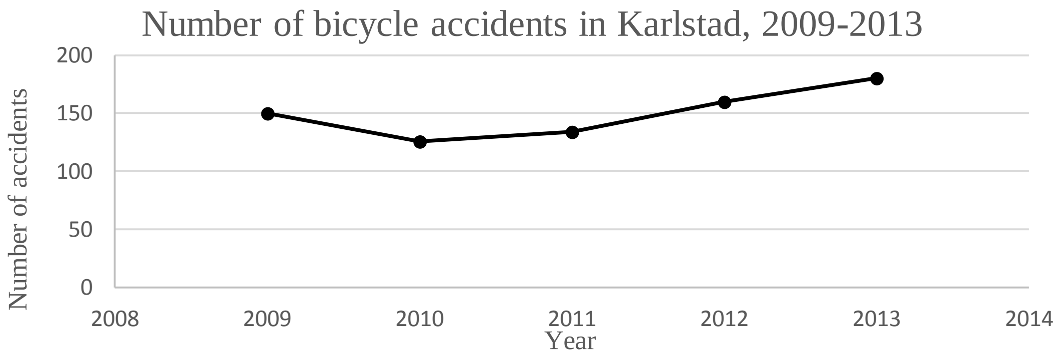

Figure 9 – The figure shows the number of bicycle accidents in Karlstad from 2009-2013.

It can be seen that there had been an increase of bicycle accidents in Karlstad from 2010 to 2013. The increase was around 54 accidents from 2009 to 2013. The bicycle accidents included all accidents in which at least one bicycle have been involved.

Which type of accident type that the bicyclist have been involved in was important to identify. The distribution for different type of accidents can be seen in the figure below.

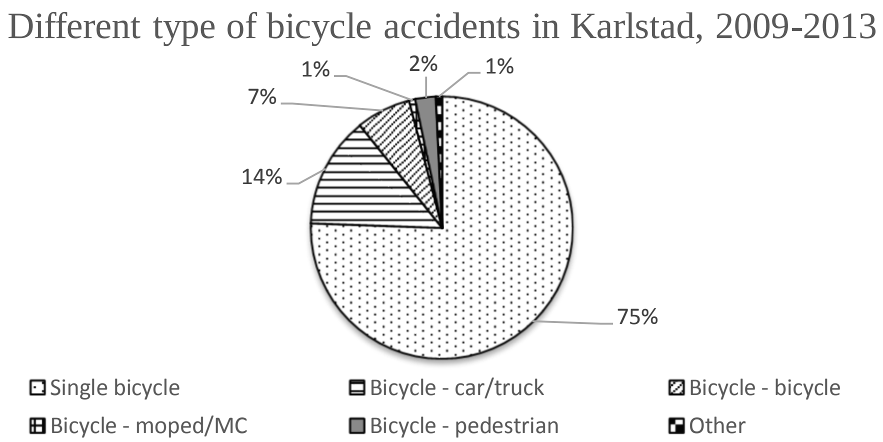

Figure 10 – The figure shows the distribution between different types of bicycle accidents in Karlstad from 2009-2013. The distribution for each type of accident was presented as a percentage of the total number of bicycle accidents.

From the figure above, it was seen that the most common accident type, with 75%, were single bicycle accidents. The second most common type, with 14%, were accidents that involved at least one bicycle and one car.

The accidents where a bicycle have been involved have different severities. The bar chart below presents the severity of bicycle accidents in Karlstad from 2009-2013.

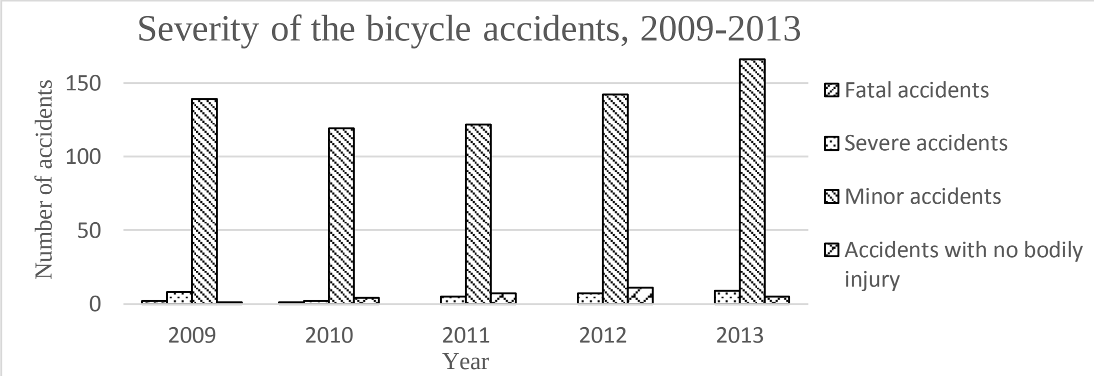

Figure 11 – The figure shows the severity of the bicycle accident in Karlstad from 2009-2013. The severity was classified from accidents with no bodily injury to fatal accidents.

It was seen that the majority of the bicycle accidents in Karlstad from 2009-2013 were minor accidents. The minor accidents (ISS< 8) had increased quite significantly from 2011-2013. The fatal accidents had decreased while the severe accidents (ISS 9+) had increased.

To get an overview of which age ranges and which sex that are most prone to bicycle accidents, a distribution of the age and sex of the persons that have been involved in a bicycle accident was compiled. The distribution was expressed as the percentage of accidents per age range of the total number of bicycle accidents and can be seen in the bar chart below.

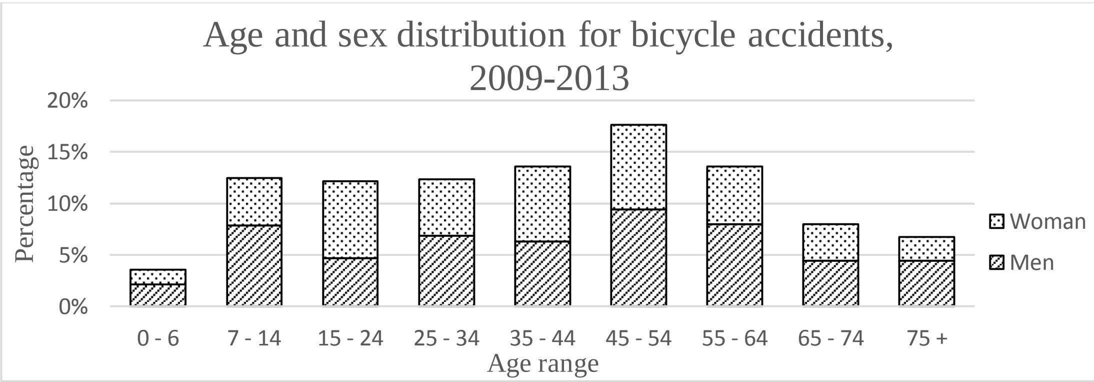

Figure 12 – The bar chart shows the distribution of the age and sex of the persons that have been involved in a bicycle accident in Karlstad from 2009-2013. The distribution was expressed as the percentage of accidents per age range of the total number of bicycle accidents.

It was seen that the age group that was most prone to bicycle accidents was bicyclists between 45-54 year, which was involved in around 17% of the bicycle accidents. However, the distribution of the accidents were relative evenly spread between the ages 7-64 years. The bicyclists between 0-6 years old were involved in the fewest accidents. The distribution between men and women were relative equal for bicyclists between the ages 25-54. Men were overrepresented in the ages 0-14 and 25+ while women were overrepresented in the ages 15-24.

4.2 Single bicycle accidents

This section presents the results over the single bicycle accident situation in Karlstad from 2009 to 2013. The single bicycle accidents chapter includes the number of bicycle accidents, different accident causes, distribution between different age ranges, variation during the year, month and day, injuries of the bicyclists and effect of helmet during the accidents.

As mentioned before in Chapter 4, and in particular Section 4.1, the majority of the bicycle accidents in Karlstad from 2009-2013 were single bicycle accidents (75%). The number bicyclists that had been involved in a single bicycle accident in Karlstad from 2009-2013 can be seen in the table below.

Table 2 – The table shows the number and the severity of the single bicycle accidents in Karlstad from 2009-2013. The severities were classified from accidents with no bodily injury to fatal accidents.

Number of accidents divided into different severity degrees						
Severity	**Number of accidents**					
		2009	**2010**	**2011**	**2012**	**2013**
Fatal accidents	0	0	0	0	0	0
Severe accidents (ISS 9+)	21	6	1	3	6	5
Minor accidents ($1 \leq ISS \leq 8$)	514	105	87	93	101	128
Accidents with no bodily injury	23	1	2	6	10	4
Total:	**558**	**112**	**90**	**102**	**117**	**137**

It was seen that the single accidents have had a similar trend as all bicycle accidents in Karlstad. It decreased from 2009-2010 and then increased with 41 accidents from 2010-2013. No fatal single bicycle accident occurred during the studied period and there were few severe accidents. However, the number of severe accidents increased with four accidents from 2010-2013.

4.2.1 Causes of the single bicycle accidents

As mentioned before, the causes for single bicycle accidents were several and it was quite often a combination of different factors. The main accident causes was manually identified through a review of the description of the bicycle accidents. The accidents were divided into the six different accident cause classifications that was mentioned in Chapter 1, and in particular Section 1.3.

To get an overview of which accidents causes that were the most common for single bicycle accident, a distribution of between the causes were compiled. The distribution included only bicyclists that had been involved in a single bicycle accident. The accidents that had insufficient information about the accidents were classified as an accident with an unknown accident cause.

The distribution can be seen in the bar chart below. The percentage for each accident cause can be seen on the bars in the chart.

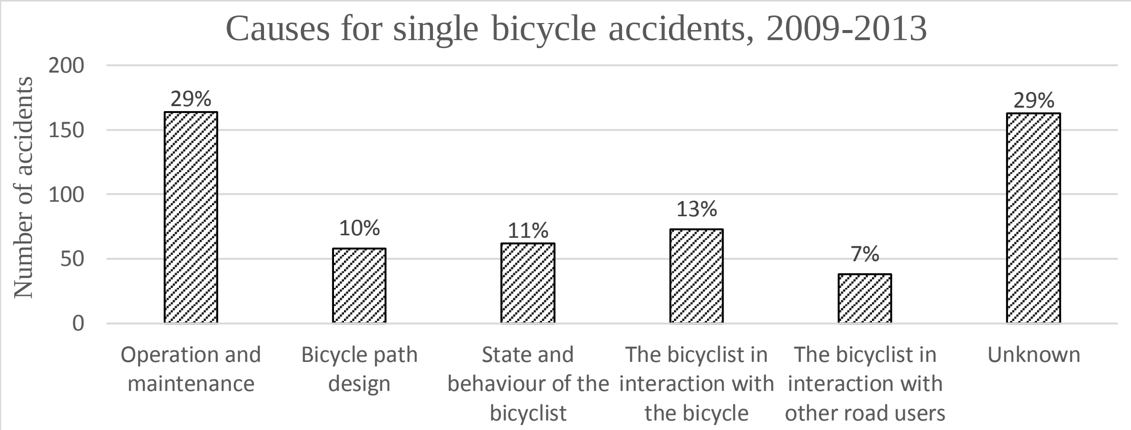

Figure 13 – The bar chart shows the distribution of single bicycle accidents in Karlstad divided into six different classifications. The statistics were from 2009-2013 and the bar chart is a result of the sum of the five years.

The main causes for single bicycle accidents in Karlstad were operation and maintenance related accidents and accidents with an unknown accident cause which each stood for around 29% of the single bicycle accidents. Compared to the operation/maintenance and unknown related accidents the four other classifications were less common. The design of bicycle paths, state and behaviour of the bicyclist and the bicyclist in interaction with the bicyclist each stood for slightly over 10% of the single bicycle accidents. Fewest single bicycle accidents occurred in interaction with other road users related accidents.

The single bicycle accidents where the bicyclist was severely injured have a different distribution between the main accidents causes. The percentage that each accident cause stood for can be seen in the table below. It is important to remember that there have been relative few severe accidents during the period so the numbers in the table below may not resemble the real life scenario.

Table 3 – The table shows the percentage for different main causes for severe single bicycle accidents in Karlstad from 2009-2013.

Main cause for accidents where the bicyclist have been severely injured	**Percentage**
Operation and maintenance	34 %
Design of bicycle paths	0 %
State and behaviour of the bicyclist	5 %
The bicyclist in interaction with the bicycle	14 %
The bicyclist in interaction with other road users	5 %
Unknown	43 %

It was seen that the accidents with an unknown accident cause was the most common accident cause. It stood for around 43% of the severe accidents. The operation and maintenance related accidents was the second most common accident cause with 34%. Design of the bicycle paths had been the main accident cause for none severe single bicycle accident during the analysed period.

4.2.1.1 Operation and maintenance

Operation and maintenance related accidents were the most common accident type and stood for around 29% of all single bicycle accidents in Karlstad from 2009-2013. 163 accidents have occurred during the period and of them were 7 severe, 148 minor and 8 without any bodily injury. The trend for the operation and maintenance related accident from 2009-2013 can be seen in the graph below.

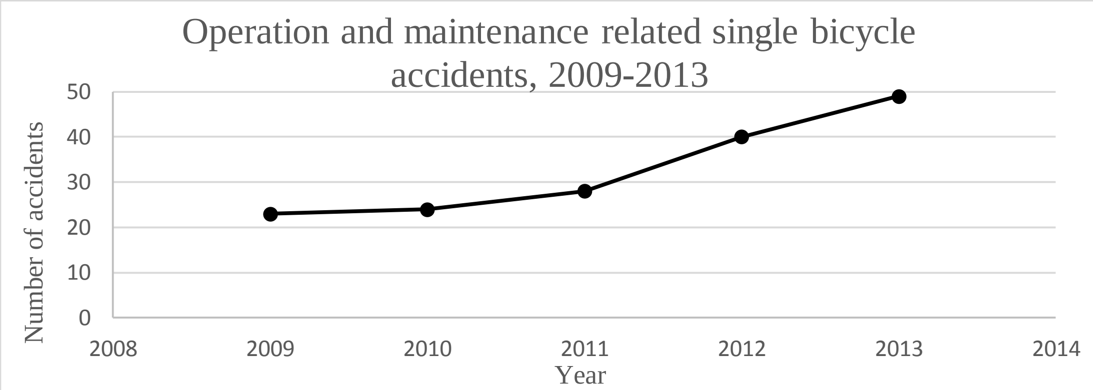

Figure 14 – The figure shows the number of operation and maintenance related single bicycle accidents in Karlstad from 2009-2013.

It was seen that there had been an increase of operation and maintenance single bicycle accidents in Karlstad from 2009 to 2013. The increase of the number of accidents were around 25 accidents from 2009 to 2013, which was an increase with approximately 100%. However, the increase of the number of accidents have been faster 2012 and 2013 as was seen in the graph above.

Through a manual review of the operation and maintenance related single bicycle accidents, several sub causes were noticed. The sub causes and the number of accidents for each sub cause can be seen in the table below.

Table 4 – The table shows the sub causes and the number of accidents for each sub cause for the operation and maintenance related single bicycle accidents.

Detailed accident cause	**Number of accidents**	**Percentage**
Slipperiness due to		
- Ice/snow	79	49%
- Sand	42	26%
- Leafs	10	6%
- Water	8	5%
Loose objects	7	4%
Holes/ uneven surface	17	10%
Total	**163**	**100%**

It was seen that the most common sub cause for the operation and maintenance related accidents were slipperiness due to ice/snow and sand. Those two sub causes stood for more than 75% of the operation and maintenance related accidents. Other common sub causes were slipperiness due to leafs or water, loose objects on the bicycle path or holes/ uneven surface.

The operation and maintenance related single bicycle accidents for 2009-2013 was separated between the months of the year. The distribution was expressed as the percentage of accidents per month of the total number of operation and maintenance related accidents. The distribution over the year can be seen in the bar chart below.

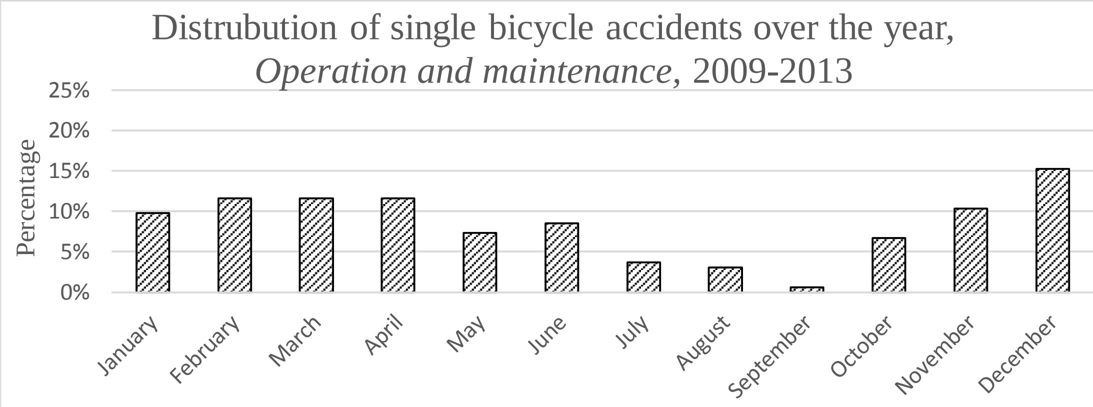

Figure 15 – The bar chart shows the distribution of operation/maintenance related single bicycle accidents over the year, expressed as the percentage of accidents per month of the total number of operation/maintenance related accidents.

It was seen that the majority of the operation and maintenance related accidents occurred during October – June. The month with the highest number of accidents was December and the one with the fewest accidents was September. The number of accidents had not a similar trend as the bicycle flow in Karlstad that was seen in Chapter 2, and in particular Section 2.2.1.

To see variations during the day, the operation and maintenance related single bicycle accidents from 2009-2013 was separated over the time of the day. From the statistics a mean for each hour was calculated and the time of occurrence was set to the middle of each hour. For example, the accidents that occurred between 02:00-03:00 the time of occurrence was set to 02:30. The same method was used in the rest of the report. Three of the accidents occurred during an unknown time of the day and were therefore not included in the daily variation.

The distribution was expressed as the percentage of accidents of the total number of operation and maintenance related accidents. The daily variation of the accidents can be seen in the graph below.

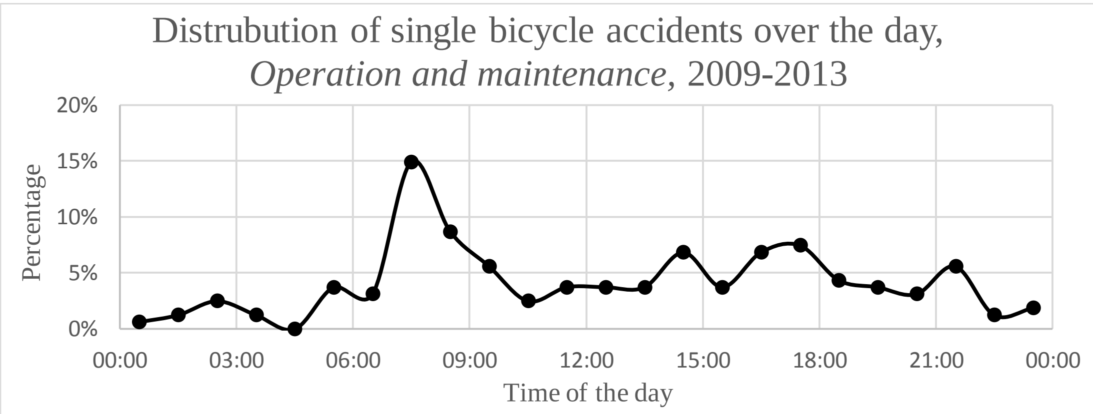

Figure 16 – The graph shows the distribution of operation/maintenance related single bicycle accidents over the day, expressed as the percentage accidents of the total number of operation/maintenance related accidents.

It was seen in the graph that it was a significant part of the operation and maintenance related accidents that occurred during the morning hours 06:30-09:30. Around 15 percentage of the operation and maintenance related accidents occurred in the morning around 07:30 from 2009-2013. That was quite a lot compared to the other hours during the day as was seen in the graph above.

4.2.1.2 Bicycle path design

Bicycle path related accidents stood for around 11% of all single bicycle accidents in Karlstad from 2009-2013. 59 accidents occurred during the period and of them were none severe, 57 minor and two were without any bodily injury. The trend for this type of accidents from 2009-2013 can be seen in the graph below.

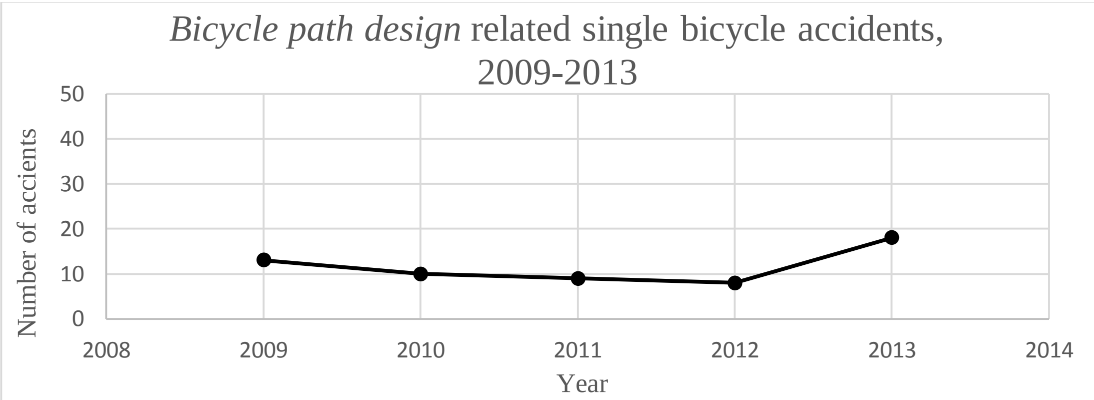

Figure 17 – The figure shows the number of bicycle path design related single bicycle accidents in Karlstad from 2009-2013.

It was seen that the number of bicycle path design related accidents slightly decreased from 2009 to 2012 and then increased quite significant during 2013. The number of accidents during 2013 increased with more than 100%, from 8 to 18 accidents, compared to 2012.

Through a manual review of the bicycle path design related single bicycle accidents several sub causes were noticed. The sub causes and the number of accidents for each sub cause can be seen in the table below.

Table 5 – The table shows the bicycle path related sub causes and the number of accidents for each sub cause for single bicycle accidents.

Detailed accident cause	**Number of accidents**	**Percentage**
Bicycled into something		
- Barrier	6	10 %
- Curb/ pavement edge	28	48 %
- Permanent installations	10	17 %
- Railway track	5	9 %
Loose cobblestones	2	3 %
Sharp corner	4	7 %
Steep downhill	2	3 %
Poor lightning	2	3 %
Total	**59**	**100 %**

It was seen that the most common sub cause for the bicycle path design related accidents was that the bicyclist have run into something. It stood for around 83% of the design related accidents. The most common things to run into were curbs/pavement edges, which stood for 48% of the accidents. Other common things to run into were barriers, permanent installations and railway tracks. Examples of permanent installations can be bus shelter, manhole covers, lamppost and so on. Loose cobblestones, sharp corners, steep areas and poor lightning were other design related sub causes.

The bicycle path design related single bicycle accidents for 2009-2013 were separated between the months of the year. The distribution was expressed as the percentage of accidents per month of the total number of bicycle path design related accidents. The distribution over the year can be seen in the bar chart below.

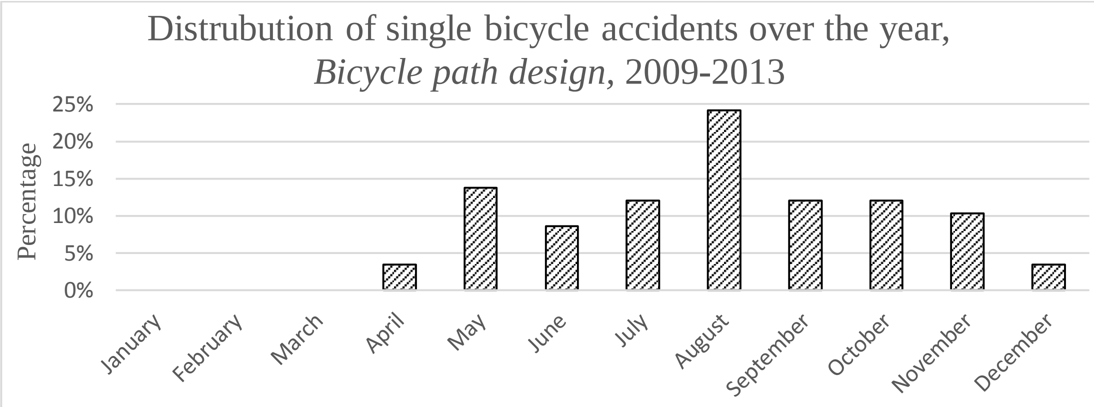

Figure 18 – The bar chart shows the distribution of bicycle path design related single bicycle accidents over the year, expressed as the percentage of accidents per month of the total number of bicycle path design related accidents.

It was seen that the majority of the bicycle path design related accidents occurred during May – November, with most accidents in August. From January to March no design related accident occurred.

To see variations during the day, the bicycle path design related single bicycle accidents from 2009-2013 were separated over the time of the day. The distribution was expressed as the percentage of accidents of the total number of bicycle path design related accidents. The daily variation of the accidents can be seen in the graph below.

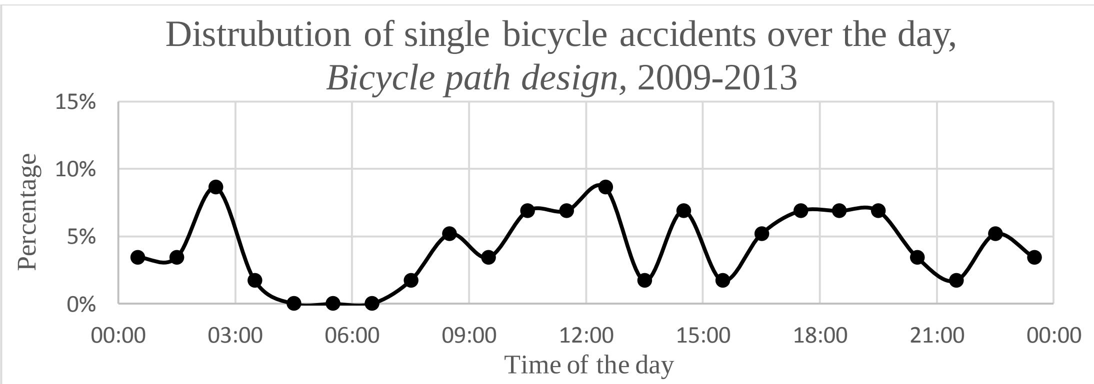

Figure 19 – The graph shows the distribution of bicycle path design related single bicycle accidents over the day, expressed as the percentage accidents of the total number of bicycle path design related accidents.

It was seen in the graph that the number of bicycle path design related accidents were relative evenly distributed during the daylight hours 09:00-12:30 and 16:00-20:00. A peak in the number of accidents in the night around 02:30 was also seen in the graph.

4.2.1.3 State and behaviour of the bicyclist

State and behaviour of the bicyclist related accidents stood for around 11% of all single bicycle accidents in Karlstad from 2009-2013. 62 accidents occurred during the studied period and of them were one severe, 59 minor and two were without any bodily injury. The trend for this type of accidents from 2009-2013 can be seen in the graph below.

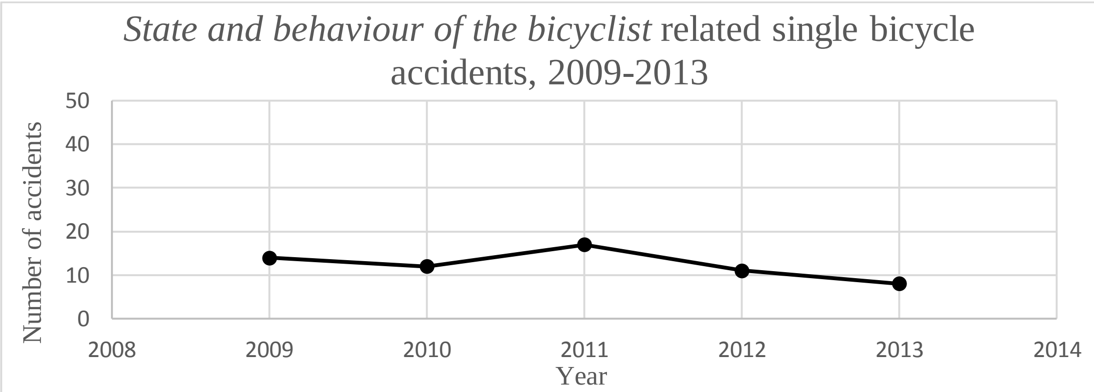

Figure 20 – The figure shows the number of state and behaviour of the bicyclist related single bicycle accidents in Karlstad from 2009-2013.

It was seen that the number of state and behaviour related accidents slightly decreased from 2009 to 2013. The number of accidents have decreased with six accidents (≈ 40%) from 2009 to 2013.

Through a manual review of the state and behaviour of the bicyclist related single bicycle accidents several sub causes were noticed. The sub causes and the number of accidents for each sub cause can be seen in the table below.

Table 6 – The table shows the state and behaviour of the bicyclist related sub causes and the number of accidents for each sub cause for single bicycle accidents.

Detailed accident cause	**Number of accidents**	**Percentage**
Suspected influence of drugs	24	39 %
Health issues	6	10 %
Inattention	11	17%
Mobile phone	3	5 %
Carried passenger	2	3 %
Lack of balance	15	24 %
Bicycled with a dog	1	2 %
Total	**62**	**100 %**

It was seen that the most common sub cause for the state and behaviour related accidents was suspected influence of drugs (39%). The most common drug was alcohol, which stood for 34% of the state and behaviour related accidents. Other common sub causes were health issues, inattention of the bicyclist and lack of balance.

The state and behaviour related single bicycle accidents for 2009-2013 were separated between the months of the year. The distribution was expressed as the percentage of accidents per month of the total number of state and behaviour related accidents. The distribution over the year can be seen in the bar chart below.

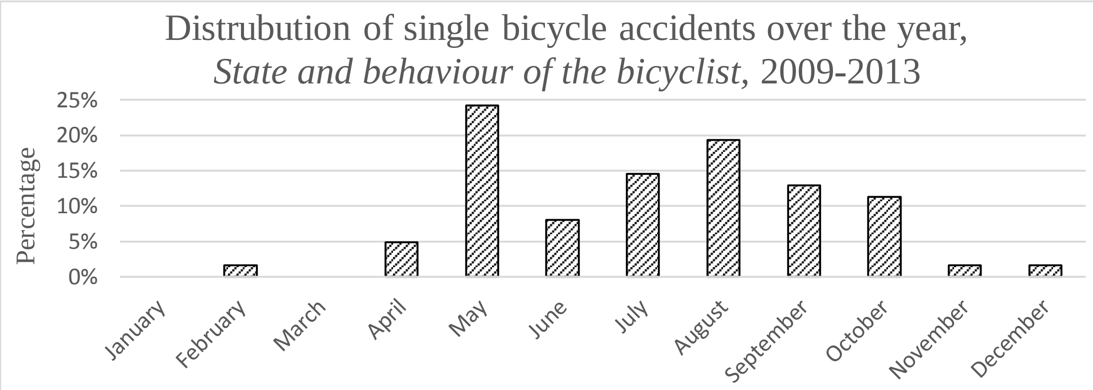

Figure 21 – The bar chart shows the distribution of state and behaviour of the bicyclist related single bicycle accidents over the year, expressed as the percentage of accidents per month of the total number of state and behaviour related accidents.

It was seen that the majority of the state and behaviour of the bicyclist related accidents occurred during May – October. Almost 25% of the accidents have occurred during May. Few state and behaviour related accident occurred from November to March.

To see variations during the day, the state and behaviour of the bicyclist related single bicycle accidents from 2009-2013 were separated over the time of the day. The distribution was expressed as the percentage accidents of the total number of state and behaviour related accidents. The daily variation of the accidents can be seen in the graph below.

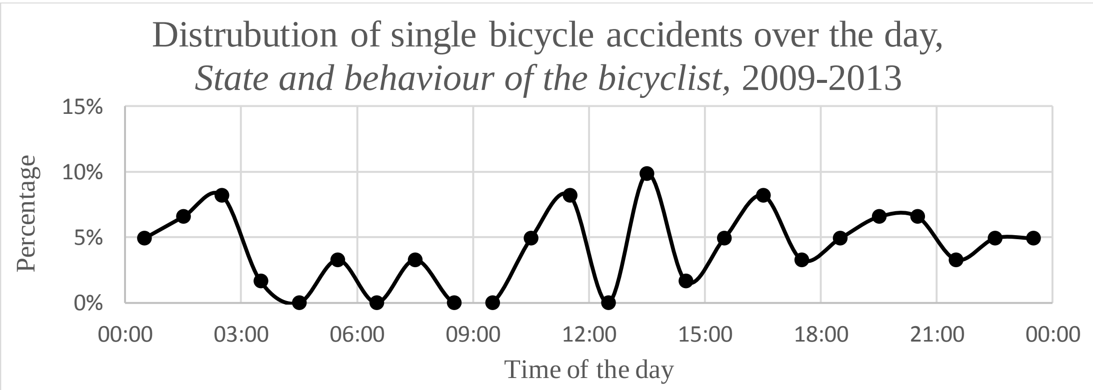

Figure 22 – The graph shows the distribution of state and behaviour of the bicyclist related single bicycle accidents over the day, expressed as the percentage accidents of the total number of state and behaviour related accidents.

It was seen in the graph above, that it was hard to find a trend for the state and behaviour related accidents over an average day. Fewest accidents occurred on the night/early morning between 03:30-0:30. There was a peak in the number of accidents on the night between 23:00-02:30.

4.2.1.4 The bicyclist in interaction with the bicycle

The bicyclist in interaction with the bicycle related accidents stood for around 13% of all single bicycle accidents in Karlstad from 2009-2013. 73 accidents occurred during the period and of them were three severe, 68 minor and none was without any bodily injury. The trend for this type of accidents from 2009-2013 can be seen in the graph below.

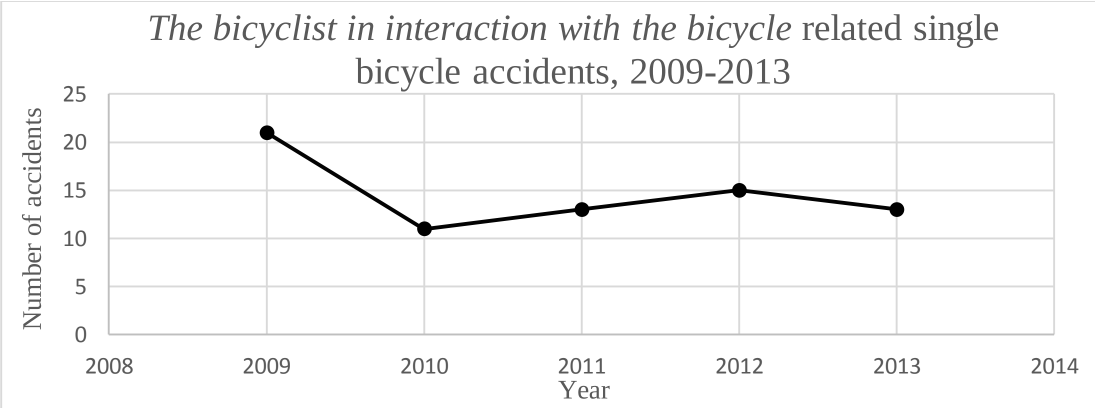

Figure 23 – The figure shows the number of bicyclist in interaction with the bicycle related single bicycle accidents in Karlstad from 2009-2013.

It was seen that the number interaction with the bicycle related accidents decreased significantly from 2009 to 2010. Since 2010, the number of accidents have slightly increased. However, the general trend since 2009 was that the interaction with the bicycle related accidents decreased.

Through a manual review of the interaction with the bicycle related single bicycle accidents several sub causes were noticed. The sub causes and the number of accidents for each sub cause can be seen in the table below.

Table 7 – The table shows the bicyclist in interaction with the bicycle related sub causes and the number of accidents for each sub cause for single bicycle accidents.

Detailed accident cause	**Number of accidents**	**Percentage**
Object in the wheel		
- Passenger's foot	5	7 %
- Drivers foot	2	3 %
- Bag	8	11 %
- Clothes	2	3 %
- Other	5	7 %
Braked to hard	13	18 %
Get on and off the bicycle	10	13 %
Slipped on the pedal	9	12 %
Malfunction of the bicycle		
- Broken chain	5	7 %
- Broken front wheel	3	4 %
- Other	9	12 %
Attached to the pedals with the feet	2	3 %
Total	**73**	**100 %**

It was seen that the most common sub cause for the interaction with the bicycle related accidents was when an object have ended up in the wheel on the bicycle (31%). The most common objects that gets in the wheel were bags/handbags, which stood for 11% of the accidents. Other common sub causes were malfunction of the bicycle (23%), that the bicyclist have braked to hard so the brakes has locked up and when the bicyclist gets on and off the bicycle. The persons that were injured when they got on and off the bicycle were often older persons.

The bicyclist in interaction with the bicycle related single bicycle accidents for 2009-2013 were separated between months of the year. The distribution was expressed as the percentage of accidents per month of the total number of interaction with the bicycle related accidents. The distribution over the year can be seen in the bar chart below.

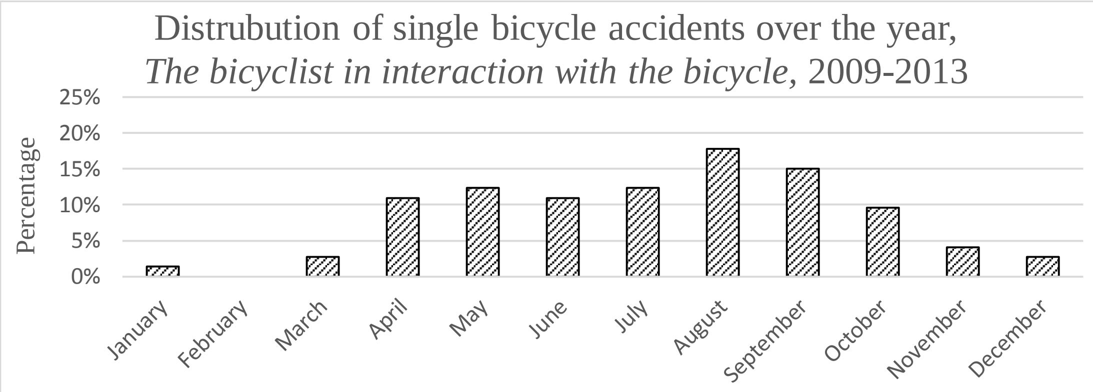

Figure 24 – The bar chart shows the distribution of the bicyclist in interaction with the bicycle related single bicycle accidents over the year, expressed as the percentage of accidents per month of the total number of interaction with the bicycle related accidents.

It was seen that the majority of the interaction with the bicycle related accidents occurred during April – October, with the most accidents in August. Few accidents occurred from November to March.

To see variations during the day, the interaction with the bicycle related single bicycle accidents from 2009-2013 were separated over the time of the day. The distribution was expressed as the percentage accidents of the total number of interaction with the bicycle related accidents. The daily variation of the accidents can be seen in the graph below.

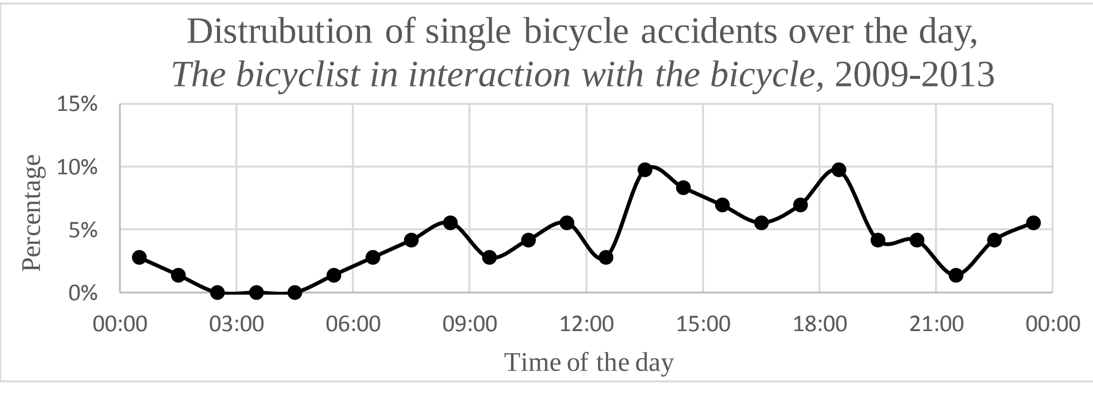

Figure 25 – The graph shows the distribution of interaction with the bicycle related single bicycle accidents over the day, expressed as the percentage accidents of the total number of interaction with the bicycle related accidents.

It was seen in the graph that the number of interaction with the bicycle related accidents were most common in the middle of the day around 13:00-19:00. Two peaks in the number of accidents at 13:30 and 18:30 was also seen in the graph above. It occurred few accidents during the night around 02:00-06:00.

4.2.1.5 Interaction with other road users

The bicyclist in interaction with other road users related accidents stood for around 7% of all single bicycle accidents in Karlstad from 2009-2013. 38 accidents occurred during the period and of them were one severe, 37 minor and none without any bodily injury. The trend for this type of accidents from 2009-2013 can be seen in the graph below.

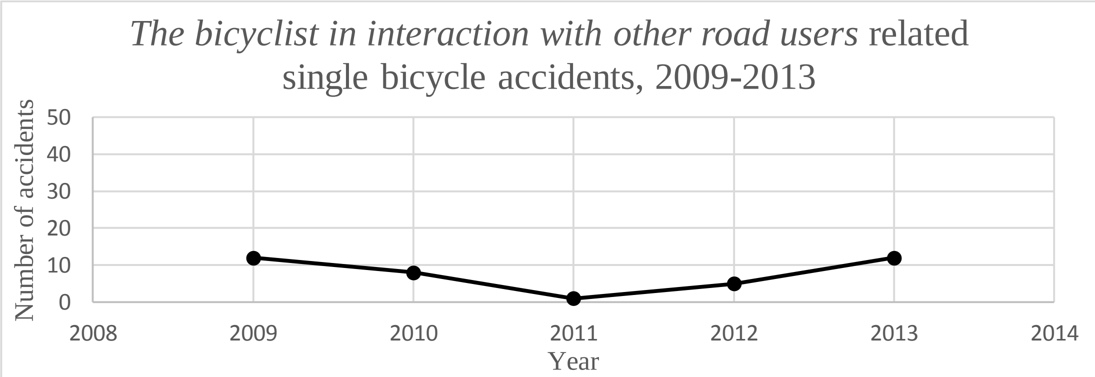

Figure 26 – The figure shows the number of bicyclist in interaction with other road users related single bicycle accidents in Karlstad from 2009-2013.

It was seen that the number interaction with other road users related accidents decreased from 2009 to 2011 and then increased from 2011 to 2013. The number of accidents in 2013 were equal to the number it was in 2009. 2011 was a good year with almost none interaction with other road users related accidents.

Through a manual review of the interaction with other road users related single bicycle accidents only one sub cause was noticed. The sub cause and the number of accidents can be seen in the table below.

Table 8 – The table shows the bicyclist in interaction with other road users related sub causes and the number of accidents for each sub cause for single bicycle accidents.

Detailed accident cause	**Number of accidents**	**Percentage**
Swerved for other road users		
- Animal	4	11 %
- Pedestrian	10	26 %
- Bicyclist	10	26 %
- Car	11	29 %
- Moped/motorcycle	3	8 %
Total	**38**	**100 %**

It was seen that the only sub cause that was identified for the bicyclist in interaction with other road users was that the bicyclist had swerved for other road user. The road uses that were most common to swerve for were pedestrians (26%), other bicyclists (26%) and cars (26%). Other road users that the bicyclist needed to swerve for were moped/motorcycles and animals. The animals that were identified were often cats or dogs.

The interaction with other road users related single bicycle accidents for 2009-2013 were separated between months of the year. The distribution was expressed as the percentage of accidents per month of the total number of interaction with other road users related accidents. The distribution over the year can be seen in the bar chart below.

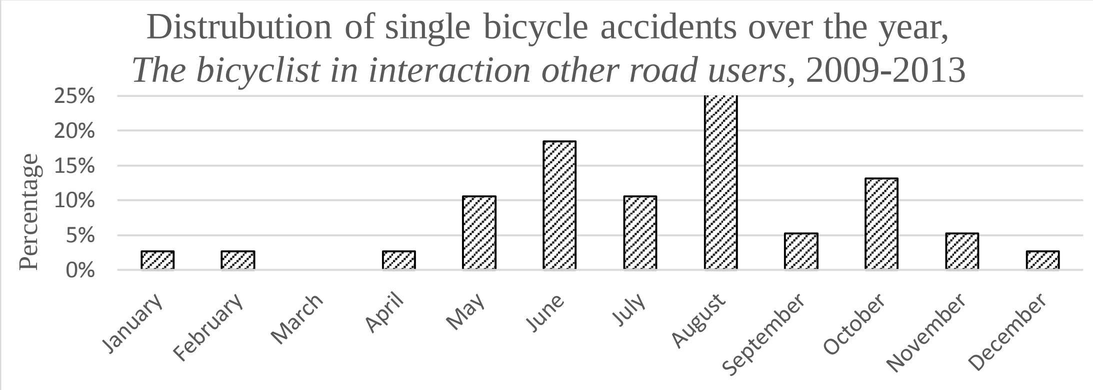

Figure 27 – The bar chart shows the distribution of the bicyclist in interaction with other road users related single bicycle accidents over the year, expressed as the percentage of accidents per month of the total number of interaction with other road users related accidents.

It was seen that the majority of the interaction with other road user related accidents occurred during May – October, with the most accidents in August. Few accidents had occurred from November to March.

To see variations during the day, the interaction with other road users accidents from 2009-2013 were separated over the time of the day. The distribution was expressed as the percentage accidents of the total number of interaction with other road users related accidents. The daily variation of the accidents can be seen in the graph below.

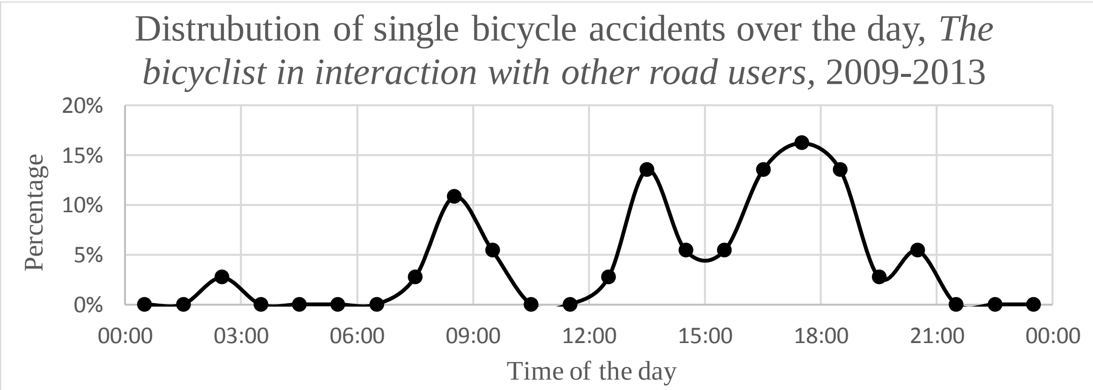

Figure 28 – The graph shows the distribution of the interaction with other road users related single bicycle accidents over the day, expressed as the percentage accidents of the total number of interaction with other road users related accidents.

It was seen in the graph that the number of interaction with other road users related accidents were most common in the middle of the day around 13:00-19:00 and in the morning around 07:00-10:00. Few accidents occurred during the evening and the night around 21:00-07:00. The distribution had a similar trend as the bicycle flow in Karlstad during the day that was seen in Chapter 2, and in particular Section 2.2.1.

4.2.1.6 Accidents with an unknown accident cause

Accidents with an unknown accident cause stood for around 29% of all single bicycle accidents in Karlstad from 2009-2013. 163 accidents had occurred during the period and of them were 9 severe, 145 minor and 9 without any bodily injury. The trend for this type of accidents from 2009-2013 can be seen in the graph below.

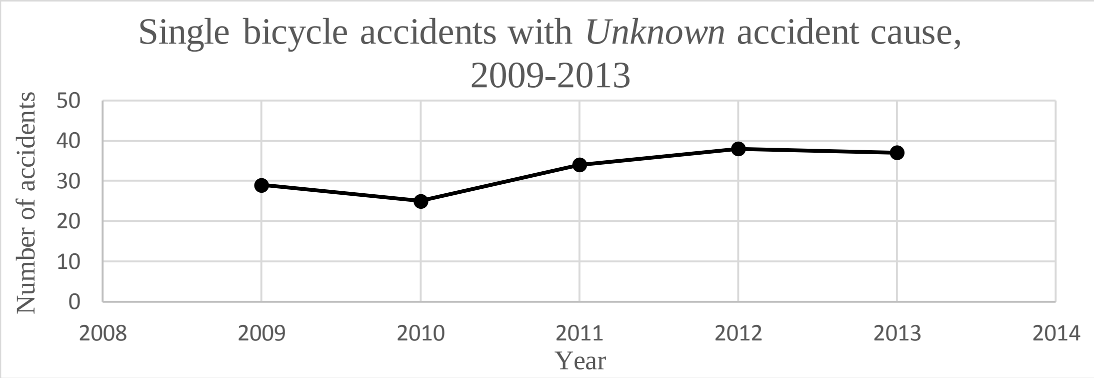

Figure 29 – The figure shows the number of bicyclist that have been involved in a single bicycle accident, in Karlstad from 2009-2013, with unknown accident cause.

It was seen that the number single bicycle accidents with unknown accident cause decreased during 2010 and then increased from 2010 to 2013. The number of accidents was relative steady the last three years of the investigated period.

Through a manual review of the single bicycle accidents with unknown accident cause only one cause was noticed. The cause was that the bicyclist had fallen, but there were not any details about the accidents, or that the accident cause was unknown. In 20% of the accidents, the bicyclist that was injured was younger than 10 years old.

The accidents with unknown accident cause from 2009-2013 were separated between months of the year. The distribution was expressed as the percentage of accidents per month of the total number of accidents with unknown accident cause. The distribution over the year can be seen in the bar chart below.

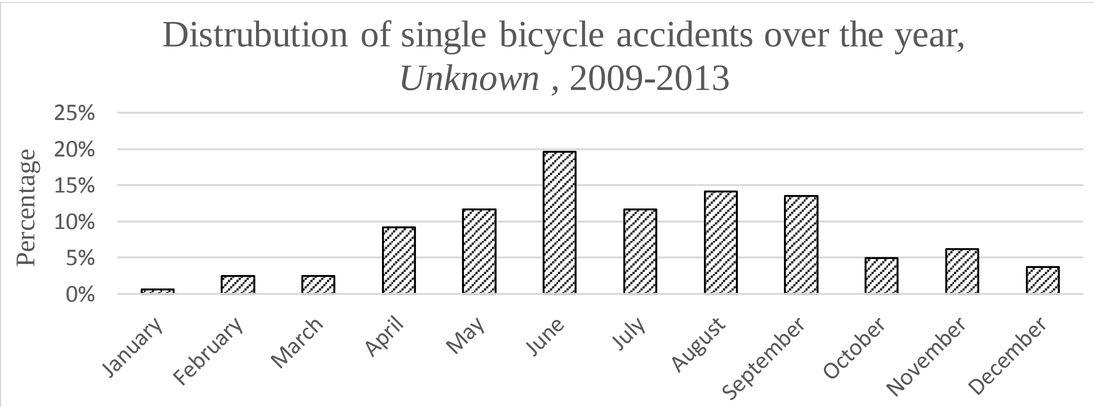

Figure 30 – The bar chart shows the distribution of accidents with unknown accident cause over the year, expressed as the percentage of accidents per month of the total number of accidents with other/unknown accident cause.

It was seen that the majority of the accidents occurred during April – November, with the most accidents in June. Few accidents occurred from January to March. The distribution was similar to the bicycle flow in Karlstad that was seen in Chapter 2, and in particular Section 2.2.1.

To see variations during the day, accidents with unknown accident cause from 2009-2013 were separated over the time of the day. The distribution was expressed as the percentage accidents of the total number of accidents with other/unknown accident cause. The daily variation of the accidents can be seen in the graph below.

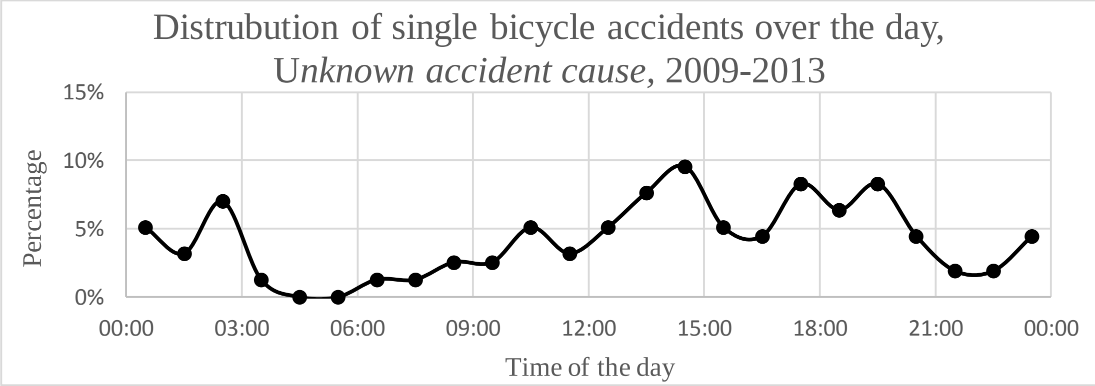

Figure 31 – The graph shows the distribution of single bicycle accidents with unknown cause over the day, expressed as the percentage of accidents per month of the total number of accidents with unknown accident cause.

It was seen in the graph that the number of accidents with unknown accident cause were most common in the middle of the day around 12:00-21:00. A peak in the number of accidents was seen in the night around 02:30. Few accidents occurred during the late night/ early morning around 03:00-07:00.

4.2.2 Distribution by age and sex for single bicycle accidents

To get an overview of which age and sex that were most prone to single bicycle accidents, a distribution of the age and sex of the persons was compiled. The distribution only included bicyclists that were involved in single bicycle accidents.

The single bicycle accidents for different age ranges were compared with all single bicycle accidents. It resulted in a probability for single bicycle accidents for different age ranges. The results can be seen in the bar chart below.

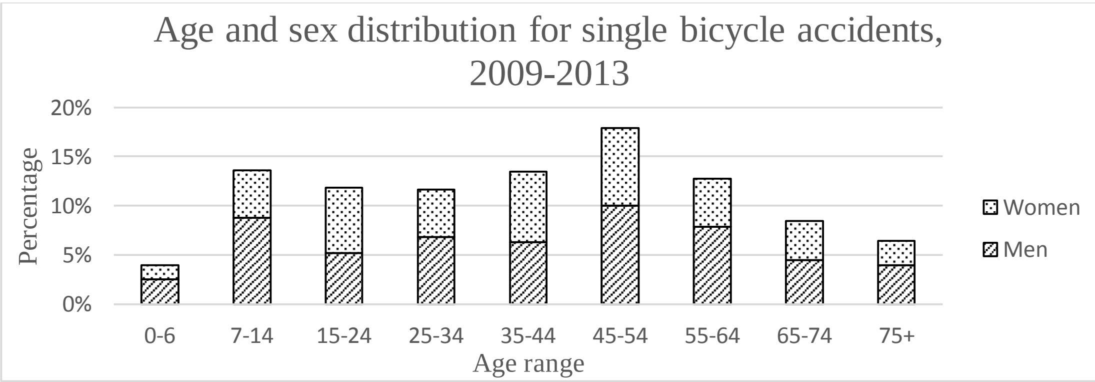

Figure 32 – The bar chart shows the distribution of the age and sex of the persons that have been involved in a single bicycle accident in Karlstad from 2009-2013. The distribution was expressed as the percentage of accidents per age range of the total number of single bicycle accidents.

It was seen that the distribution the single bicycle accidents was similar to the distribution of all bicycle accidents. The age group that was most prone to single accidents were bicyclists between the ages 45-54. Subsequently was the distribution of the accidents relative evenly spread between the ages 7-44 and 55-64 years. The bicyclists between 0-6 years old were involved in the fewest accidents. Men was overrepresented in the most of the age ranges.

Around 88% of all bicycle accident for the ages 0-6 years were single bicycle accidents. It was seen that the age ranges with the lowest probability for single accidents were bicyclists in the ages between 15-64 and 75+, which the probability were under 80%.

For different age ranges, different accident causes were more or less common. The main accident causes for different causes can be seen in the fraction chart below. Each accident cause was expressed as the fraction of all accidents for the corresponding age range.

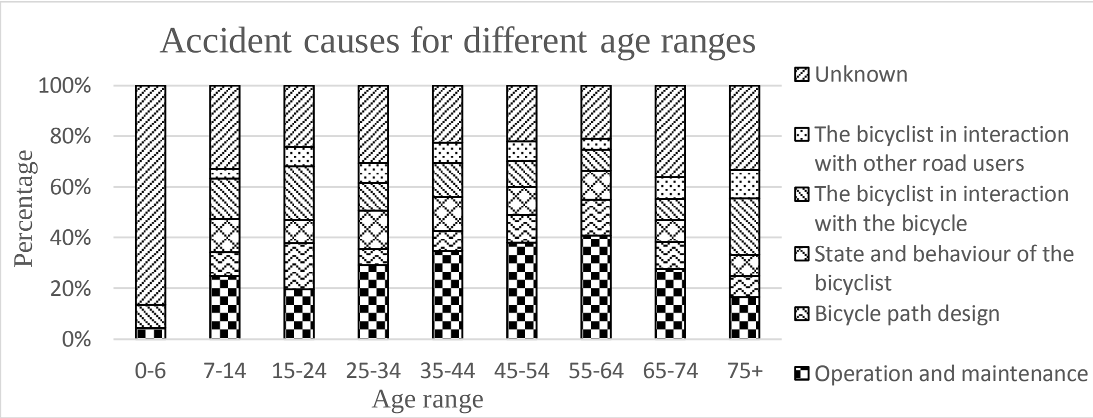

Figure 33 – The fraction chart shows the main accident causes for different age ranges. Each accident cause was expressed as the fraction of all accidents for the corresponding age range.

In the fraction chart above it was seen which accident cause that was most common for each age range. Operation/maintenance and unknown related accidents were often the most common accident causes for the age ranges. For bicyclists that were older than 75 years old, interaction with the bicycle was more common compared to the other age ranges. Bicyclists that were younger than seven years old have often an unknown accident cause.

The environments that the different age ranges are traveling in/stay in might influence the distribution of the accident causes.

4.2.3 Distribution of the single accidents over the year, week and day

The distribution of the occurrence of single accidents during the year and day were interesting information that was compiled from the data from STRADA. The data resulted in two bar charts, one for the distribution over the year and one for the distribution over the week, and one graph, for the distribution over the day.

The single bicycle accidents for 2009-2013 were separated between the months of the year and the distribution over the year can be seen in the bar chart below. The distribution was expressed as the percentage of accidents per month of the total number of single bicycle accidents.

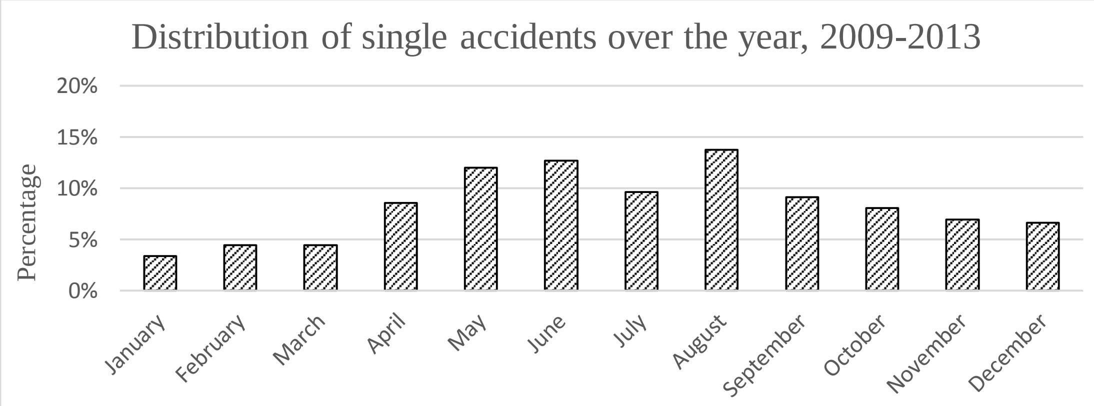

Figure 34 – The bar chart shows the distribution of single bicycle accidents over the year, expressed as the percentage of accidents per month of the total number of single bicycle accidents.

The number of single accidents during 2009-2013 had a similar trend as the bicycle flow in Karlstad that was seen in Chapter 2, and in particular Section 2.2.1. As was seen in the figure above, the most number of single accidents occurred during the summer months. Fewest single accidents occurred during the winter months January, February and March.

The single bicycle accidents for 2009-2013 were separated between the days of the week and the distribution over the week can be seen in the bar chart below. The distribution was expressed as the percentage of accidents per day of the total number of single bicycle accidents.

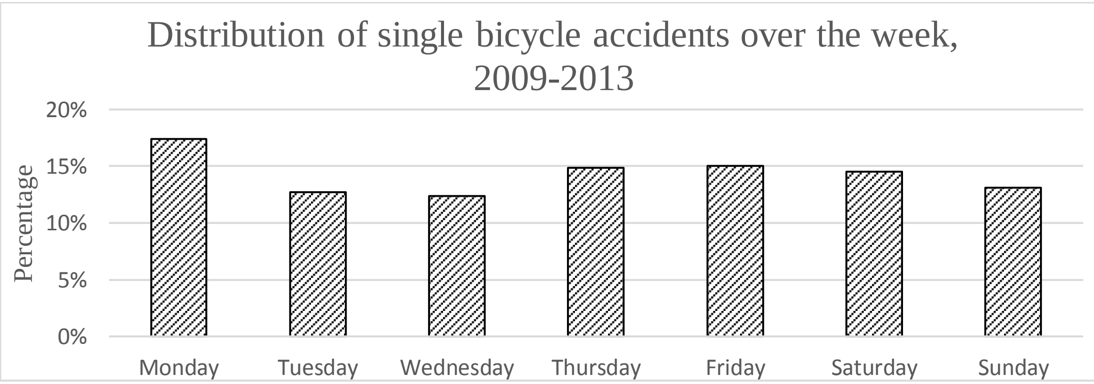

Figure 35 - The bar chart shows the distribution of single bicycle accidents over the days of week, expressed as the percentage of accidents per day of the total number of single bicycle accidents.

The number of single accidents during 2009-2013 had not a similar trend as the bicycle flow in Karlstad during the week that was seen in Chapter 2, and in particular Section 2.2.1. As was seen in the figure above, the most number of single accidents occurred during Mondays. Fewest single accidents occurred during Tuesdays and Wednesdays.

The accidents causes were more or less common for the different days of the week. How large part of each main cause that have occurred on the different days can be seen in the fraction chart below.

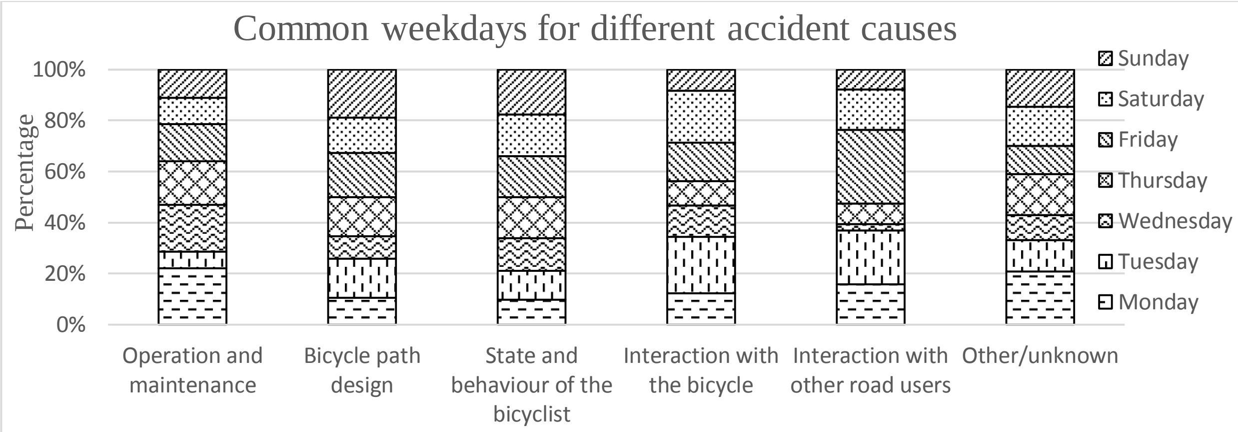

Figure 36 – The fraction chart shows which day of the week that were the most common for different accident causes.

It was seen that operation and maintenance related accidents were most common during Mondays and the least common during Wednesdays and the weekend. The bicycle path design and state/behaviour of the bicyclist related accidents had a relative large part of the accidents occurring during the weekends and Friday. The interaction of other road users related accidents were most likely to occur during Fridays. The accidents with unknown accident cause were relative evenly distributed over the days of the week, but slightly more common during Mondays.

Twelve of the single bicycle accidents had occurred during an unknown time on the day. These twelve accidents were not included in the results of the distribution over the day. The distribution of single bicycle accidents over the day can be seen in the graph below, expressed as the percentage of accidents per hour of the total number of single bicycle accidents.

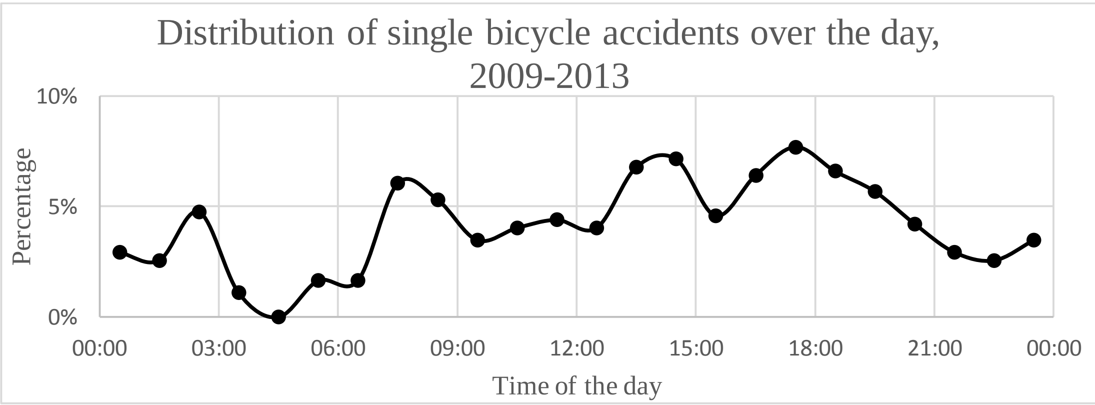

Figure 37 – The graph shows the distribution of single bicycle accidents over the day, expressed as the percentage accidents of the total number of single bicycle accidents.

The number of single accidents during 2009-2013 did not have a similar trend as the bicycle flow in Karlstad during the day that was seen in Chapter 2, and in particular Section 2.2.1. As was seen in the figure above, the most number of single accidents occurred during the daylight hours, around 07:00-20:00. However, there was a peak in the number of accidents on the night, around 22:00-02:00. Fewest single accidents occurred during the early hours, around 03:00-06:00.

4.2.4 Road type for the single bicycle accidents

The single bicycle accidents have occurred on several different type of locations in Karlstad. The road types where the accidents occurred were described in STRADA. The different types of road types was manually identified and the result can be seen in the table below.

Table 9 – The table shows which road types that the single bicycle accidents have occurred in Karlstad, from 2009-2013.

Road type	Number of accidents	Percentage
Crossing	28	5 %
Other	5	1 %
Parking space	14	2 %
Sidewalk	26	5 %
Street intersections	17	3 %
Street/road	195	35 %
Unknown	29	5 %
Walking/bicycle path	244	44 %
Total	**558**	**100 %**

It was seen that the most accidents occurred on walking/bicycle paths (44%) and on streets/roads (35%). Other road types that were relative common were crossings for pedestrians/bicyclists, sidewalks and street intersections. Five percent of the accidents had occurred on an unknown road type.

4.2.5 Injuries due to single bicycle accidents

The severity of the single bicycle accidents in Karlstad were mentioned in the first part of Chapter 4, and in particular Section 4.2. However, the number of bicyclists that needed institutional care were not mentioned. The total of bicyclists that needed institutional care due to a single bicycle accident were 46 persons from 2009 to 2013. The bicyclists that needed institutional care were further analysed in Chapter 5, and in particular Section 5.7.

A manual review of the accidents was performed. This in order to see which type of injuries and which body parts that were the most common to injure in a single bicycle accident. Which type of injuries and the percentage for each type can be seen in the table below. It is important to remember that one bicyclist can sustain several different type of injuries in one accident.

Table 10 – The table shows which type of injuries that bicyclists have sustained in single bicycle accidents in Karlstad from 2009-2013.

Type of injury	**Percentage**
Crush/clamping	9.1 %
Dislocation/sprain	1.6 %
Internal organs	5.9 %
Joints/muscle ligaments	3.4 %
Other	2.8 %
Skeletal/fracture	30.4 %
Wound	11.7 %
Whole area	35.1 %

It was seen that the most common type of injury were whole area injuries, which stood for around 35% of the injuries. The type whole area includes many different type of injuries such as wounds, bruises and much more (Marmon, 2015). The second most common injuries were skeletal/fracture, which stood for around 30% of the injuries. Internal organs stood for 5.9% of the injuries and the majority of them were head injuries.

Which body parts that were injured and the percentage for each type can be seen in the table below. It is important to remember that one bicyclist can have injured multiple body parts in one accident.

Table 11 – The table shows which body parts that bicyclists have injured in single bicycle accidents in Karlstad from 2009-2013.

Body part	**Percentage**
Arm	2.8 %
Elbow	7.4 %
Face/ Head	30.0 %
Finger	4.0 %
Foot	4.9 %
Hand	15.3 %
Hip	4.1 %
Knee	10.2 %
Leg	1.5 %
Other	3.2 %
Shoulder	11.0 %
Sternum/ thorax	3.9 %
Thigh	1.8 %

The most common body part to injure was the face/head that stood for around 30% of all body parts that have been injured. Usual injury types for the injuries in the face/head were whole area, wounds and skeletal injuries. Other body parts that were relative common to injure were hands, shoulders and knees.

4.2.6 Use of helmet

As mentioned before, there have occurred 558 single bicycle accidents in Karlstad from 2009 to 2013. In 139 of the accidents it was noted that the injured bicyclists had used helmet. In other words, 25% of all bicyclists that visited the emergency hospital or contacted the police, due to a single bicycle accident, used helmet at the time of the accident. It was only around 4% of the injured bicyclist, which had used helmet at the time of the accident, which have suffered from a concussive injury. This can be compared with the percentage of bicyclist that have suffered from a concussive injury without a helmet, which was around 8%.

As mentioned before 46 bicyclists needed institutional care due to single bicycle accidents in Karlstad from 2009 to 2013 and of them 26% suffered from a concussive injury. Of the bicyclists that needed institutional care, 10 had used helmet. In other words, 21% of the bicyclists that needed institutional care had used helmet at the time of the accident. Only two of the 10 bicyclists, that had used helmet and needed institutional care, suffered from a concussive injury.

5 Analysis of the Single Bicycle Accidents in Karlstad

Both the bicycle accidents and the single bicycle accidents in Karlstad have increased since 2010. Karlstad is not the only municipality in Sweden that have an increase of bicycle accidents. As mentioned in Chapter 4, and in particular Section 4.1, the severe bicycle accidents have increased in Sweden in general. The single bicycle accidents were further analysed in this chapter. The following topics have been analysed; a general analysis, areas prone to accidents, accidents on the bicycle paths in Karlstad, the different accident causes, the occurrence of the accidents in the year and day and bicyclists that needed institutional care.

5.1 Single bicycle accidents in Karlstad

As was mentioned before, both the single bicycle accidents and the number of bicyclists have increased in Karlstad from 2011 to 2013. It is important to remember that the statistics over the number of bicyclists are modified values from two monitoring stations in Karlstad that was mentioned in Chapter 2, and in particular Section 2.2. The number of bicyclists on Sandbäcksgatan and by Sandgrund have increased with 16.5% during the analysed period while the number of single accidents increased with 34.3%. It was noticed that the accidents increases faster than the number of bicyclists. More bicyclist will likely result in that the bicycle paths will be higher trafficked. The increase in the number of injured bicyclists was mainly due to an increase for the accidents classified as an operation/maintenance, bicycle path design or interaction with other road users. The six classifications was separately discussed in Section 5.4.

The accidents in Karlstad have increased the last years, but the question is if Karlstad have been more prone to single bicycle accidents than the rest of Sweden. Karlstad have quite high percentage of the population that uses their bicycle as the main transportation mode. According to Spolander's theory that the traffic safety for bicyclists are higher in cities with high usage of the bicycle would result in a good traffic safety for bicyclists in Karlstad. In an attempt to answer the question, the number of single bicycle accidents per million bicycle trips was calculated. The calculations are described later in this chapter.

In Chapter 2, and in particular Section 2.2, the bicycling in Karlstad was described. Central Karlstad and Skåre had together a population of 66 000 in 2009 and 69 000 in 2013. According to the recent regional travel survey, 21% of the citizens have used the bicycle as the main transportation mode during 2014. It is important to have in mind that the regional travel survey do not include children. However, in a report by Spolander it was stated that during 2011-2012, 16% of the population in Karlstad uses their bicycle as the main transportation mode. In Chapter 2, and in particular Section 2.1, it was mentioned that a person makes 1.62 main travels each day. The previously stated information was used to calculate both the number of single bicycle accidents per million bicycle trips in Karlstad.

Number of single bicycle accidents per million bicycle trips

The number of single bicycle accidents per million bicycle trips was estimated to see how traffic safety for bicyclists in Karlstad was compared to Sweden in general.

The population in Karlstad was set to the mean value for the period, in other words 67 500. The percentage of the population that used their bicycle as the main transportation mode was set to 16% due to that the studied period was 2009-2013. The number of bicycle trips with the bicycle in Karlstad were calculated to 32.0 million during the period. With 558 single bicycle accidents during the same period the number of accidents per million bicycle trips were calculated to 17.5. In the report of Spolander the number of accidents per million bicycle trips varied from 8-43. That placed Karlstad in the middle in the statistics, which also was the case in Spolander's report where Karlstad also placed themselves in the middle. Karlstad is according to the calculations slight below the average value of 18.3 accidents per million bicycle trips in Sweden.

The number of single bicycle accidents per million bicycle trips for 2013 was also calculated. The population was set to 69 000 and the percentage of the population that uses the bicycle as the main transportation mode set to 18.5% instead of 16%. The value 18.5% is the mean percentage for the percentages for 2014 and 2011-2012. The number of bicycle trips with the bicycle in Karlstad were calculated to 7.6 million during 2013. With 137 single bicycle accidents during the period the number of accidents per million bicycle trips was calculated to 18.1.

A small increase from 17.5 to 18.1 in the number of injured bicyclists in single bicycle accidents per million bicycle trips can be seen. It is important to remember that 17.5 is a mean for the years 2009-2013 and 18.1 is the value for 2013. Yearly variations in weather most likely affect both the number of bicyclist and the number of injured. It is therefore hard to say if the traffic safety in Karlstad have been decreased or that it is due to the weather variations. The value calculated for 2013 must be considered with caution due to the many factors affecting the number of bicyclists and accidents.

5.2 Areas prone to accidents

Around 25% of the single bicycle accidents had an uncertain location. However, through a manual review of the accident locations for the accidents with an uncertain location it was seen that the majority of the accidents had in most cases stated a street name or/and a district. Only two accidents had not stated a district or a street name as the location of the accident.

Areas prone to accidents were located with help of GIS. A map over the intensity of the accidents was made through an analysis of the locations of the accidents in GIS. The analysis was performed with help of a built in function in GIS that was called *Intensity map*. The intensity of the accidents were dependent on both how many accidents that were within the chosen distance and how close they were to each other. Several locations were relative uncertain and due to this a distance of 150m was selected. 150m was judged to be a sufficient distance due to that all single bicycle accidents were included in the intensity map.

The result can be seen in the figure below. The black lines are major bicycle paths, which are presented in Karlstad's bicycle map. The intensity scale goes from black to red, where red are the areas with a high intensity of accidents.

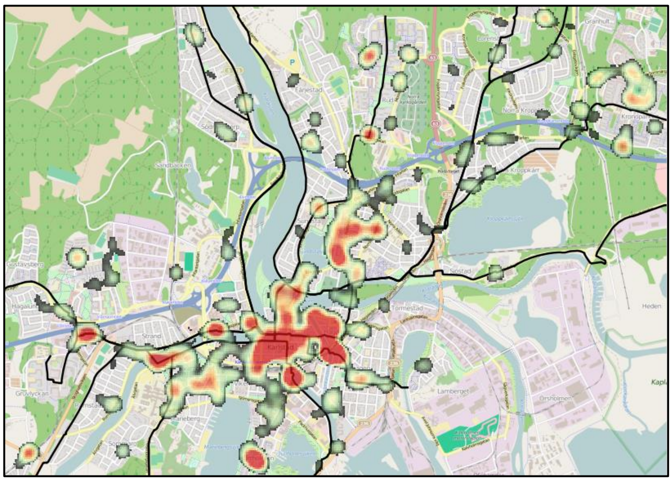

Figure 38 – The figure shows a map over the intensity of the single bicycle accidents that have occurred in Karlstad from 2009-2013. The black lines are major bicycle paths, which are presented in Karlstad's bicycle map. The intensity scale goes from black to red, where red are areas with a high intensity of accidents.

The highest concentrations of single bicycle accidents were found in the central parts of Karlstad. A large continuous area with a high intensity can be seen in the central parts. Nevertheless, several locations outside the central parts had accumulations of accidents, which can be seen in the map. Some accumulations of accidents can not be seen in the map above because they are located outside further away from the central part than the map covers.

A zoomed in map over the central parts can be seen below.

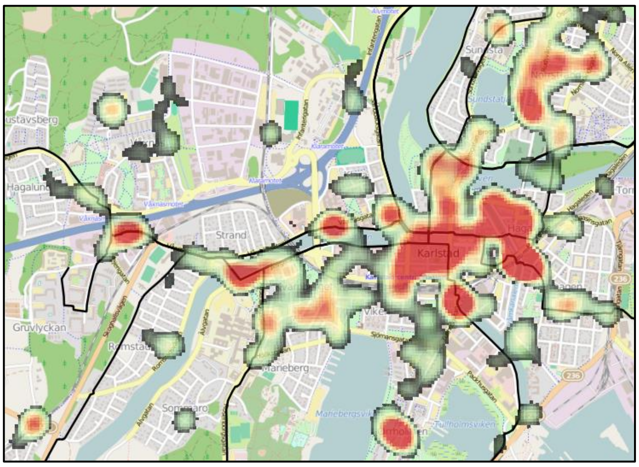

Figure 39 – The figure shows a map over the intensity of the single bicycle accidents that have occurred in Karlstad from 2009-2013. The map is zoomed in on the central parts of Karlstad. The black lines are major bicycle paths, which are presented in Karlstad's bicycle map. The intensity scale goes from black to red, where red are areas with a high intensity of accidents.

As was mentioned before, the highest numbers of single bicycle accidents were found in the central parts of Karlstad. The large continuous area with a high intensity with its centrum around Drottninggatan and the square can easier be seen in the zoomed in map. Some of the accumulations relative close to the central parts can also be seen in the map above. An accumulation was seen at the inner harbour of Karlstad. The area in the inner harbour was rebuilt and finished in 2011/2012. Therefore is that accumulation not mentioned in the report. However, it had been interesting to see any potential effects on the number of accidents due to the rebuilding.

5.2.1 Accidents in the central parts of Karlstad

That there were many accidents in the central parts was expected due to that the central parts have a high number of bicyclists and other road users. Two locations in the central parts had a higher intensity than other areas in the central parts. These two were the major road through Karlstad, Drottninggatan, and by the square in Karlstad. The two locations was perceived to have one of the highest amounts of pedestrians/bicyclists in Karlstad, which most likely affects the several accidents. The accident causes were relative even distributed on these two locations, however there were three accident causes that were more common than the other was. These three were accident interaction with the bicycle related accidents, design related accidents and accidents with unknown accident cause. The three accident causes that were more common in the central parts of Karlstad are discussed below.

Accidents with an unknown accident cause were the most common type of single bicycle accidents in the central parts in Karlstad. It was hard to draw any conclusions about the accidents because of the insufficient information regarding the accidents and that the accidents not were concentrated on small areas. The description of the accidents were often only that the bicyclist have fallen with the bicycle and the circumstances were not mentioned. It might be easy for the bicyclist to only fill in that he or she have crashed with the bicycle without mentioning anything more. This was a problem when analysing the situation for the bicyclists in Karlstad.

The interaction with the bicycle accidents that had occurred in the central parts of Karlstad had several different causes for the accidents. That the bicyclists braked too hard, that the bicyclists got an object in the wheel, stepping on and off the bicycle and so on. That there were several interaction with the bicycle related accidents might be explained by a combination of that there are a many people that bicycle in the central parts of Karlstad, that there is a lot of persons in motion and that bicyclists often get on and off the bicycle in the central parts.

Several design related accidents were due to that the bicyclist have run into things like curbs or fixed installations. That the bicyclist collide with fixed installations can have several different reasons. It do not necessary have to do with an improperly design, but it can be an effect of it. Other reasons can be that the bicyclist have been inattentive, overestimated their own ability and so on. Accidents when the bicyclist have run into curbs can be a consequence when the bicyclists transport themselves from one side of the road to the other.

A significant part of the accidents that happen during the night occurred in the central parts of Karlstad. The accidents that occurred during the night is further analysed in Chapter 5, and in particular Section 5.6.

5.2.2 Accidents outside the central parts of Karlstad

To identify locations with high concentrations of accidents outside the central parts of Karlstad one more analysis in GIS was performed. The analysis was performed with buffer zones to see in which areas it occurred five or more accidents within a radius of 100m. This was done in order to decrease the importance of the distance between the accidents compared to the previous analysis. This due to that several accident locations were relative uncertain. As mentioned before, in the previous analysis the intensity was higher the closer to each other the accidents have occurred. If two accidents mistakenly were placed right next to each other, the intensity will be unreasonable high.

Several areas with high intensities of single bicycle accidents were identified from the analysis. The locations with high concentrations of accidents were similar to the previous intensity analysis but there were fewer areas located in the analysis with the buffer zones. A combination from the two analysis was used to see which areas that were most prone to accidents outside the central parts. In other words, areas with high intensities of accidents and where it have happened five or more accidents within a radius of 100m was identified with help of the two analyses. The most interesting areas from the two analyses are analysed and discussed below.

<u>Bridges</u>

Karlstad has several watercourses in the city, which have led to that the city have several bridges. High intensities of accidents were found on some of the bridges that crosses a watercourse and at the ramps to the bridges.

Of the accidents that occurred on or in connection with a bridge the majority were operation and maintenance related. Other common accident causes were interaction with the bicycle related, state and behaviour related and accidents with an unknown accident cause. The operation and maintenance related accidents were mainly due to slipperiness on ice, snow, sand or water. An explanation for the ice and sand accidents on the bridges in Karlstad could be that bridges had a higher probability of slipperiness due to ice. This might be due to that cold air cools down the road surface both from above and below. Bridges that crosses a watercourse seems to have a higher risk for slipperiness. This might be due to that the air has a higher humidity, compared to bridges that not crosses a watercourse. Windy conditions on bridges may be a potential accident cause for bicyclists. That in combination with that the bicyclist transports an object may be dangerous due to that the wind can get hold of the object resulting in an accident. Windy conditions might also influence the slipperiness accidents.

Of the accidents that have occurred on a ramp to a bridge the majority were operation and maintenance related. Other common accident causes were interaction with the bicycle related and accidents with an unknown accident cause. The operation and maintenance related accidents were due to slipperiness on ice or sand. The interaction with the bicycle related accidents can be due to that the bicyclist have braked to hard so the brakes have been locked resulting in a sudden stop. From site visits on the bridges in Karlstad, it was seen that the connection between the bridges and the ramp often was sharp (around 90˚). Some of the bridges was vaulted so the velocities of the bicyclists was often higher around the ramp than on the middle of the bridges. High velocities and sharp corners are most likely affecting both the operation/maintenance and the interaction with the bicycle related accidents. Slipperiness accidents often occur in connection with turns and high velocities increases the probability for an accident. In some places the connecting road was quite narrow which likely also contributed to the high concentration of accidents at the ramps. No interaction with other road users was identified at the ramps, however it is important to remember that it was only the single bicycle accidents that are analysed.

Ankersbron by Herrhagen

The location that was one of the most prone to accidents in Karlstad was at Herrhagen by a bridge named Ankersbron. Ankersbron bridge is located around 500m east of the central parts of Karlstad. One of the eight major bicycle paths in Karlstad passes the bridge. For knowledge, one of Karlstad's largest nightclubs is located just east of the bridge.

The bridge is quite narrow (only 2.6m wide) and there is a quite steep first part of the bridge on each side. The ramps is narrow on each side and the connection with the bicycle path is sharp, around 90˚. Two photos of the bridge can be seen in the figure below.

Figure 40 – The photo shows Ankersbron bridge at Herrhagen in Karlstad. The photo to the left shows the west side of the bridge and the one to the right shows the east side. The area around the bridge has one of the highest intensities of single bicycle accidents in Karlstad.

Single bicycle accidents occurred on both sides of the Ankersbron and on the bridge as well. However, the majority of the accidents have occurred on the bridge, the bridge ramps and on the east side of it. Measurements of the amount of bicyclists in the area cannot be found. However, during a site visit in the area the amount of bicyclists and pedestrians perceived to be relative large. The site visit was in the middle of April in the afternoon.

The accidents that occurred on the bridge or the ramp were mainly operation/maintenance related and interaction with the bicycle related. The operation and maintenance related accidents were due to slipperiness on ice or sand. Why it occurred several single bicycle accidents on bridges in Karlstad was previous analysed and discussed. However, this bridge was particularly prone to accidents. It was likely due to that the bridge and ramps were very narrow, the ramps had a quite high inclination and the connection to the bicycle path were sharp. Slipperiness in combination with high speeds and sharp turns are likely to be the main reason for the operation and maintenance related accidents. This in combination with a high amount of pedestrians and bicyclists likely increase the probability for an accident. The interaction with the bicycle accidents can be due to that the bridge are narrow and that the bicyclists have had problem to manage the bicycle properly.

The accidents on the east side of the bridge were mainly operation/maintenance related, interaction with the bicycle related or accidents with an unknown accident cause. On the east side of the bridge, there is a quite steep downhill down to the bridge from Herrhagen. The downhill is not only steep but also quite long so high velocities can be reached for bicyclists. The downhill seems to influence the number of accidents in the area. It might be that several of the accidents have had high velocities as the main accident source, even if the accidents not were classified as a state and behaviour related accident. This was due to that high velocities were not mentioned in any accident description for the accidents in the area.

Some accidents have occurred on the west side of the bridge. From the information in STRADA it seemed that the accidents mainly was been caused by interaction with other road users. Right after the bridge the combined pedestrian and bicycle path is quite narrow, when going towards the central parts of Karlstad. As previously mentioned, it was perceived that quite a lot pedestrians and bicyclists were in motion in the area. The narrow pedestrian and bicycle path in combination with many other road users might be an explanation for the accidents on the west side.

One of the largest nightclubs in Karlstad is located just east of the bridge. A question that comes up was if the nightclub effected the intensity of the accidents in the area. After the analysis of the accidents, the conclusion was that it might affect some of the accidents. Around 30% of the accidents in the area around Ankersbron have occurred after 22:00 and around 20% of the accidents in the area occurred after 00:00. Alcohol might be a one of the reason for accidents in the area, however it was judged to have affected maximum 20-30% of the accidents due to the time that the accident have occurred. Almost all accidents that have occurred during the night have occurred on the east side of the bridge (the same side as the nightclub) which might be an indication that alcohol have been involved. However, the design of the bridge/ramps, the narrow pedestrian and bicycle path and the steep downhill was assumed to have a larger effect on the accidents.

That this location was one of the most prone to accidents was probably due to several different reasons. Poorly designed bridge/ramps (from a safety perspective), a narrow pedestrian and bicycle path, a steep downhill and that one of the largest nightclubs are located in the area is likely to affect accident rates here.

Våxnäs, in the area around the bus stop Spårgatan

Våxnäs is a residential area west of the central parts of Karlstad. Two of the major bicycle paths connects the area to the central parts. An accumulation of single bicycle accidents was found on the bicycle paths relative close to the bus stop Spårgatan. The accidents were mainly due to operation and maintenance. The operation and maintenance related accidents mainly occurred due to slipperiness on ice, snow or sand. This might be an indication of that the operation and maintenance are less good in the area. Still, the question is what the accumulation of accidents were caused by.

A site visit was performed to study the area and gather information that was used in the analysis. Two photos of the area can be seen in the figure below.

Figure 41 – The photos shows the area around the bus stop Spårgatan at Våxnäs where it have occurred several single bicycle accidents.

The bicycle path in the area felt well designed and the number of road users was perceived to be relative high. When the flow from the monitoring stations in Karlstad were analysed, indications of relative high bicycle flows in the area was found. However, higher flows were found on other locations in Karlstad. During the site visit, it was seen that the bicycle path was a combined bicycle and pedestrian path, as can be seen in the photos above, and the question is if the width of the path are sufficient for the bicycle flow in the area. Interaction with other road users might have contributed to the several operation and maintenance related accidents.

The bicycle path crosses entrance roads on two locations in the area, which are interaction points between bicyclists and cars/motor vehicles. The car traffic in the area were perceived to be relative high. This have likely affected the several accidents in the area.

The question is if it is a coincidence that there are many accidents in the area, if it is due to the bicycle/pedestrians path combined with a relative high bicycle flow, if it is due to the crossings of the entrance roads or that the operation and maintenance in the area is less good. It is very hard to say why just this area is prone to accidents. It can be a result of a combination of all that was mentioned above. However, no conclusion for the area can be drawn.

5.3 Accidents on the bicycle paths in Karlstad

As mentioned before, it have occurred 558 single bicycle accidents in Karlstad during 2009-2013. In STRADA, it was mentioned that 255 (46%) of the accidents have occurred on any type of bicycle path. An analysis in GIS was performed to see how many accidents that have occurred on the major bicycle paths in Karlstad. The analysis was performed with help of a buffer zone around the major bicycle paths and all accidents within that zone were included in the analysis. From the analysis, it was seen that it was around 175 (31%) of the accidents that have occurred on one of the major bicycle paths in Karlstad.

The single bicycle accidents that have occurred in Karlstad can be seen in the figure below. The blue dots are accidents that occurred on one of the major bicycle paths while the red dots are accidents that not occurred on a major bicycle path.

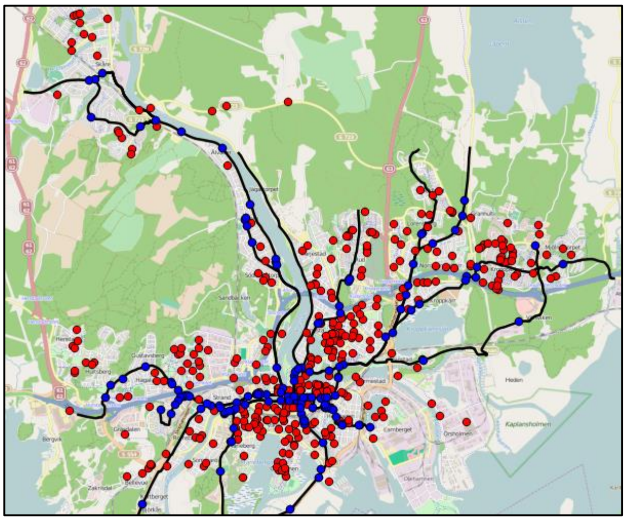

Figure 42 – The figure shows the single bicycle accidents in Karlstad that have occurred during 2009-2013. The blue dots were accidents that occurred on one of the major bicycle paths and the red dots were accidents that not occurred on a major bicycle path.

Some of the major bicycle paths in the figure above seems to have a tendency to have more accidents the other. However, it is quite hard to identify with such zoomed out map. Some areas without a major bicycle path where it have happened several accidents can also be identified in the map above.

The accidents causes for the accidents that have occurred on the major bicycle paths was analysed in order to see if there were any differences between the accidents that have occurred on a major bicycle path and the ones that not occurred on a bicycle path. Both the accidents from the analysis in GIS and from STRADA were analysed. The result can be seen in the bar chart below. The dotted line in the bar chart represents the distribution between the accident causes for all single bicycle accidents that was shown in Chapter 4, and in particular Section 4.2.1.

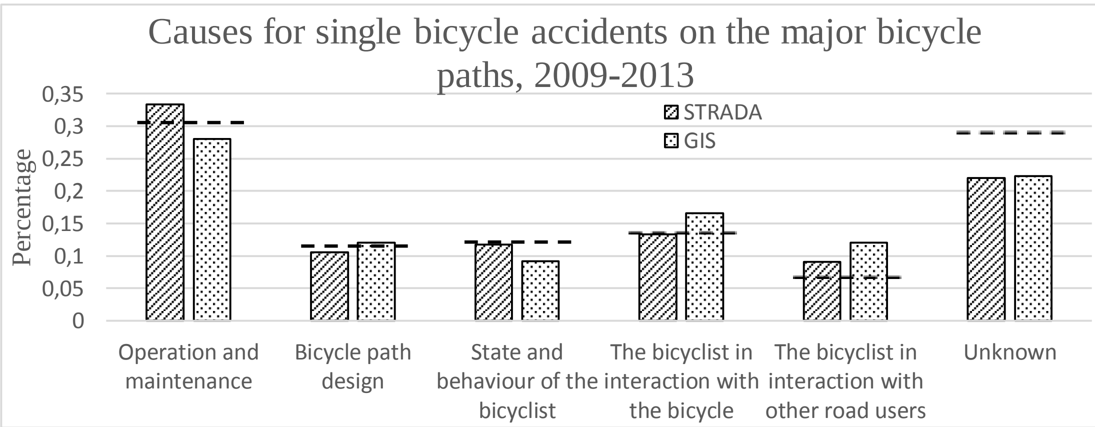

Figure 43 – The bar chart shows the distribution between different accident causes for the single bicycle accidents that have occurred on a bicycle path. The striped bars represents the accidents that have occurred on any bicycle path (STRADA) and the dotted represents the accidents that have occurred on a major bicycle path (GIS). The

dotted line in the bar chart represents the distribution between the accident causes for all single bicycle accidents.

It can be seen in the figure above that the single bicycle accidents that have occurred on any bicycle path (the striped bars) and the accidents that have occurred on a major bicycle path (the dotted bars) have the same trend. The difference between the bars and the dotted line was surprisingly small. For some of the accident causes there were some larger differences between the bars. The operation and maintenance related accidents were less common on a major bicycle path compared to accidents that have occurred on any bicycle path. Karlstad prioritize the bicycle paths when it comes the snow and ice clearance, especially the major bicycle paths. This can be an indication of that the operation and maintenance are better on the major bicycle paths compared to the other bicycle paths.

It was seen in the bar chart that the percentage accidents with an unknown accident cause that have occurred on a bicycle path are less compared with the percentage for all single bicycle accidents.

5.4 Accident causes

It have not occurred so many single accidents where the bicyclist have been severely injured in Karlstad during the analysed period. Due to this, the comparison with the literature were performed with all single accidents for Karlstad. However, it is important to remember that from here and on the statistics for Karlstad are for all single bicycle accidents and the one from the literature study are for bicyclists that are severely injured.

The accident causes for the single bicycle accidents in Karlstad were mentioned in Chapter 4, and in particular Section 4.2.1. As mentioned, the operation/maintenance related and the accidents with unknown accident cause was the two most common accident causes in Karlstad which each stands for 29% of the single accidents. This can be compared with the different accident causes for the accidents where the bicyclist became severely injured in Sweden in general, which was mentioned in Chapter 2, and in particular Section 2.3.1. From the literature, the majority of the accidents had an unknown accident cause (39%) and operation/maintenance and the bicyclist in interaction with the bicycle was the second most common accident cause, which each stood for 17% of the accidents.

If the accident causes for Karlstad are compared with the literature study, it was noticed that the number of accidents with unknown accident cause was lower in Karlstad than in Sweden in general. Two potential reasons for this may be due to that the emergency hospital in Karlstad are good in reporting accidents or/and that the bicyclist are better at giving a detailed accident description. Another reason can be that an accident with an unknown accident cause was more common for severe accidents due to loss of memory in the accident situation. For the other accident causes, the percentage and relationship between the accident causes were similar for Karlstad as in Sweden in general. The six different main classifications for the accident causes are below analysed and discussed separately.

To analyse where the different accident causes occur a map over the intensity of the accidents was made through an analysis of the accidents in GIS for each accident type. The analysis was performed with help of a built in function in GIS that was called *Intensity map*. The intensity of the accidents is dependent on both how many accidents that are within the chosen distance and how close they are to each other. Several locations of the accident were relative uncertain and due to this a distance of 300m was selected. As previously mentioned, the location of the accidents were in several cases relative uncertain. Due to this, the statements connected with this analysis should be treated with caution. However, through a manual review of the accident locations it was seen that the majority of the accidents had in most cases stated a street name or/and a district as the location of the accident.

5.4.1 Operation and maintenance accident causes

The single bicycle accidents that had operation and maintenance as the main accident cause were the most common accidents in Karlstad. In an attempt to see why it is the most common one, a more detailed analyse of the operation and maintenance related accidents was performed. The analysis was partly based on the result that was presented in Chapter 4, and in particular Section 4.2.1.1.

The number of accidents with operation and maintenance as the main accident cause have increased significantly 2012 and 2013 was mentioned in the result chapter. It was also mentioned that the most common sub causes for the accidents are slipperiness due to ice, snow and sand. The slipperiness accidents due to snow or ice have also increased significantly during 2012 and 2013. Between 2011 and 2012, the slipperiness accidents due to ice/snow increased with 300%. Slipperiness due to ice, snow and sand together stood for around 75% of the operation and maintenance related accidents. The distribution of the operation and maintenance accidents over an average year was shown in Chapter 4, and in particular Section 4.2.1.1 and it was seen that the majority of the accidents occurred during November – June.

Why the number of bicycle accidents caused by operation and maintenance have increased was hard to say, especially when no significant increase in the number of bicyclists during the winter have been seen. When talking about slipperiness related accidents it is important to remember that yearly variations of the weather affect the number of accidents. Some winters are more prone to slipperiness than other is and some winters have very low temperatures so few bicyclists uses their bicycle. However, one potential reasons for the increased number of slipperiness related accidents might be that the number of bicyclists 2012 and 2013 have increased during the months January to March. The majority of the slipperiness accidents occurred during December, which is contradictory to the previous mentioned theory. Nevertheless, a significant part occurred during the months January – April as well. Yearly variations and that the number of bicyclists only were from two monitoring stations in Karlstad, which may result in inaccuracies in the statistics, might have affected the results. It can be that the number of bicyclists have increased while the number of bicyclists were underestimated for 2012 and especially 2013.

The ages of the bicyclist that are involved in the accidents varies, but the most common age ranges were 35-64 and especially 45-54. That there were fewer accidents for the ages 25-35 may be due to that the bicyclists are better in manoeuvring the bicycle. The percentage of persons older than 65 years old and younger than 24 years old are lower compared to the percentage for all single bicycle accidents. One potential reason for this can be that elderly and young persons uses their bicycle less during the winter months compared with other age ranges.

It was analysed if the increased number of accidents could be due to that more elderly people have been injured during the winter months the last years. In the analysis, it was noticed that it was actually the other way around. The number of injured bicyclists over 65 years old have decreased 2012 and 2013 compared to 2010 and 2011 while the bicyclists that are younger than 35 years old have increased.

5.4.1.1 Time of the accidents

As mentioned before, the majority of the accidents occurred during the autumn, winter and spring. This was expected because slipperiness was the most common accident cause, which stood for 86% of all operation and maintenance related accidents. Slipperiness due to leafs are most common during the autumn when the trees shed their leaves. Slipperiness due to ice/snow are most common during November to March depending on how the winter was. Slipperiness due to sand were most common March to May with its peak in April.

The accidents were more common during the weekdays, with the exception on Tuesdays. Most accidents occurred on Mondays and the number of injuries have a steady decline towards the weekend. That the majority of the accidents occur during the weekdays were reasonable because the number of bicyclists were higher during those days.

From the result in Chapter 4, and in particular Section 4.2.1.1, it was discovered that there was a peak in the number of accidents in the morning around 07:00-09:00. Through a more detailed analysis of the accidents that occurs in the morning, it was seen that it was mainly the accident that was caused by slipperiness due to ice or snow that resulted in the peak in the morning. The distribution of the slipperiness accidents due to ice or snow over an average day can be seen in the graph below.

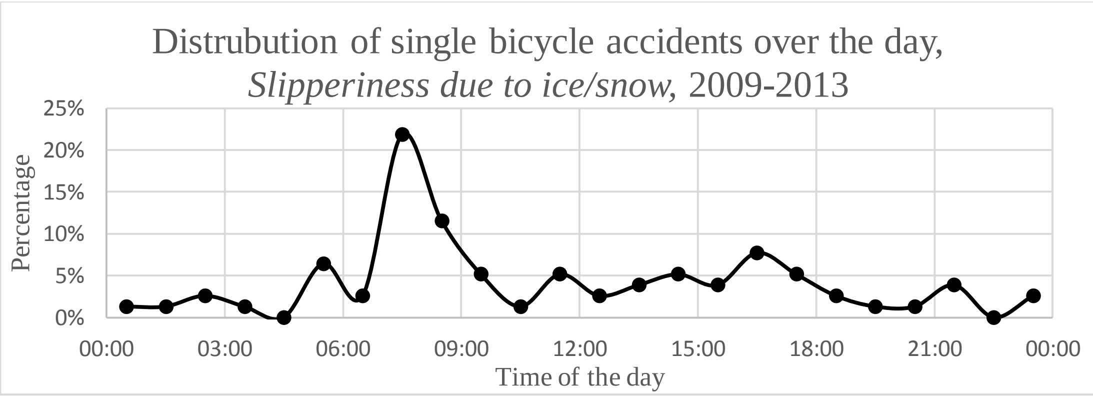

Figure 44 – The graph shows the distribution of single bicycle accidents caused by slipperiness due to ice or snow over an average day, expressed as the percentage accidents of the total number of single bicycle accidents.

A significant part of the slipperiness accidents due to ice and snow occurred in the morning hours around 07:00-09:00 and a small peak was seen in the afternoon. Many bicyclist transport himself or herself to and home from work, which results in a large flow in the morning and afternoon. The morning peak for the accidents is likely to be associated with which time and where the snow clearance starts in the morning. This due to that the flow are high both in the morning and the afternoon but the majority of the accidents occur in the morning. The snow clearance might start too late so the bicycle paths still are icy or snowy when the bicycle commuters travel in the morning.

It can also be that the snow clearance needs to start earlier in some specific areas to decrease the number of accidents. In many cases the snow clearance capacity is limited which result in that some bicycle paths may be prioritized. In the next part, Section 5.4.1.2, the locations of the slipperiness accidents were analysed to see how the accidents were related to the major bicycle paths in Karlstad.

The snow clearance was assumed to be the main cause for the morning peak. However, the slipperiness accidents in the morning can also be affected by other parameters as the behaviour of the bicyclists, design of the bicycle path and so on. In the manual review of the accidents in the morning it was noticed that in several of the accidents the bicyclists have stated that they have been stressed on their way to work. How other parameters effect the operation and maintenance related accidents are analysed and discussed in Section 5.4.1.2.

5.4.1.2 Location of the accidents

Around 16% of the operation and maintenance related accidents had an uncertain position of the accidents. Due to this, the statements connected with this analysis should be treated with caution. However, through a manual review of the accident locations it was seen that the majority of the accidents had in most cases stated a street name or/and a district as the location of the accident.

The result from the intensity analysis in GIS can be seen in the figure below. The black lines are major bicycle paths, which are presented in Karlstad's bicycle map. The intensity scale goes from black to red, where red are the areas with a high intensity of accidents.

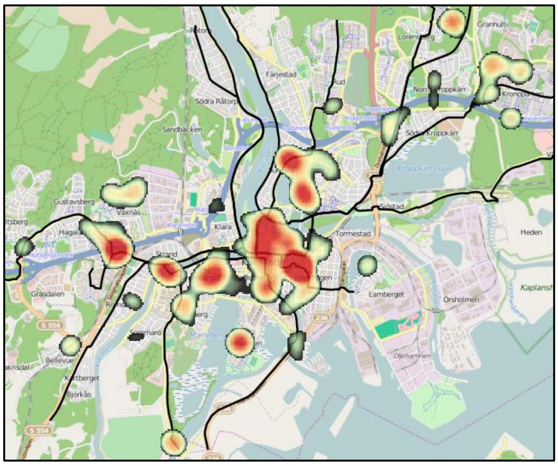

Figure 45 – The figure shows a map over the intensity of the operation and maintenance related accidents that have occurred in Karlstad from 2009-2013. The black lines are major bicycle paths. The intensity scale goes from black to red, where red are the areas with a high intensity of accidents.

It can be seen that the majority of the accidents occurred in the central parts. However, accumulation of accident can be found at several of the bridges in Karlstad, at Ankersbron bridge, at Våxnäs and several more locations. Bridges, Ankersbron bridge and Våxnäs are locations that are prone to single bicycle accidents in general and have been analysed and discussed in Chapter 5, and in particular Section 5.2.2. It is important to remember that this are only accumulations of accidents, the majority of the accidents are widely spread over the city and may not be included in any accumulation. Several of the accumulations were located near or on the major bicycle paths. To see if the majority of the accidents occurred on the major bicycle paths one analysis in GIS and one review of the accidents was performed. The analysis was performed with buffer zones around the major bicycle paths to see how many that have occurred within those zones.

From the analysis with GIS, it was seen that around 30% of the operation and maintenance accidents occurred on the major bicycle paths in Karlstad. The results from the analysis in GIS might not fully correspond to the real life scenario because the location of many accidents are relative uncertain.

If the statistics in STRADA is analysed it was seen that in 55% of the accidents have the bicyclist stated that the accident have occurred on a bicycle path. The bicycle path can be both minor and major in this case.

It is hard to say why only 30% of the accidents occurred on one of the major bicycle paths and 55% occurred on any bicycle path. Possible reasons for this can be that the bicycle paths are well maintained and therefore less prone to accidents, that the bicycle paths are not so well maintained so the bicyclists choses other roads, that the bicycle paths are not so well planned so the bicyclists choses other roads due to this and so on.

5.4.1.3 Influence of other accident causes

That the most accident occur due to operation and maintenance might have something to do with that it is an easy cause to name. Accidents may often be a combination of several accident causes but often is slipperiness and roughness easy to distinguish and therefor blamed. It can be accidents that are connected with for example the road design but the operation and maintenance was still blamed as the main accident cause. This can be in locations where there are sharp corners and so on.

As mentioned before, accumulation of accidents were found at several of the bridges in Karlstad, at Ankersbron bridge, at Våxnäs and several more locations. Bridges, Ankersbron bridge and Våxnäs are locations that are prone to single bicycle accidents in general and have been analysed and discussed in Chapter 5, and in particular Section 5.2. It is important to remember that this are only accumulations of accidents, the majority of the accidents are widely spread over the city and might not be included in any accumulation.

If there are accidents that was described as an operation and maintenance related accident but in reality has another main accident cause was hard to determine. However, ramps to bridges, the design at the accumulation by Våxnäs, sharp turns and downhills are areas that this might be the case. Våxnäs have many interaction points between cars and bicyclists, which can result in sudden braking manoeuvres. Sudden braking manoeuvres often increase the probability for a slipperiness accident in bad weather or/and road conditions.

If many operation and maintenance accidents have occurred during turns is hard to determine due to the uncertain position and insufficient accident description of many accidents. For 16% of the slipperiness accidents in STRADA it was mentioned that the accident have occurred in combination with a turn. It was more common to that the bicyclist have slipped on sand (26%) in combination with a turn than ice/snow (10%). Thus, it is important to remove sand early in areas with sharp corners and in intersections. The accidents are not necessary defined as the wrong type of accident just because it has been specified that these accidents have occurred in combination with a turn. It depends on the surroundings, both the design and other road users. It can be bicyclists that slips in intersections even though it is well designed due to that they are going to turn.

5.4.2 Bicycle path design

The single bicycle accidents that has bicycle path design as the main accident cause were not so common in Karlstad. Only 10% of the accidents were classified as a bicycle path design related accident. A more detailed analysis of the accidents were performed to see if any interesting findings could be found. The analysis was partly based on the result that was presented in Chapter 4, and in particular Section 4.2.1.2.

The number of accidents with bicycle path design as the main accident cause have increased during 2013 compared to 2009-2012 as mentioned in Chapter 4, and in particular Section 4.2.1. The distribution of the accidents over an average year was also shown. It was seen that the majority of the accidents occurred during May – November, with the highest amount of accidents in August. It was also mentioned that the most common sub cause was that the bicyclists have bicycled into a curb or pavement edge. That the bicyclists have run into a curb/pavement edge or a fixed installation do not necessary be due to an improper design, this was analysed and discussed in Chapter 5, and in particular Section 5.4.2.3.

That the number of accidents have increased during 2013 may be explained by the increase in the number of bicyclists in Karlstad. That the bicycle path design related accidents were highest during the summer months were likely due to that the number of bicyclists also were highest during the summer. Bicycle path design are not as weather sensitive as the operation and maintenance related accident. Nevertheless, yearly variations of the weather may affect the number of accidents.

The ages of the bicyclist that are involved in the accidents varies, but the most common age ranges were 15-24 and 45-64. That there were fewer accidents for the ages 25-44 may be due to that the bicyclists are better in manoeuvring the bicycle and evaluate situations then older and younger persons.

5.4.2.1 Time of the accidents

As mentioned before, the majority of the accidents occur during the summer months. This was expected because the number of bicyclists are higher during the summer, which was seen in Chapter 2, and in particular Section 2.2.1.

The bicycle path design related accidents were relative evenly spread over the days of the week, but it occurred slightly more accidents on Fridays and Sundays. That the bicycle path design related accidents were high on Sundays while the number of bicyclist on Sundays were low was an interesting finding. A manual review of the accidents that occurred on Sundays was performed, but no significant correlation between the accidents was found.

From the result in Chapter 4, and in particular Section 4.2.1.2, it was seen that a significant part of the accidents occurred on the morning and late afternoon. A small peak in the number of accidents was seen on the night around 02:00-03:00. That a large part of the accidents occurred in the morning was expected due to that the number of bicyclists are high then. A higher number of bicyclists often results in a higher number of accidents due to that the bicycle paths are more crowded and more people bicycle. The accidents that occurred on late afternoon and on the night was a more interesting finding. The accidents that occur during the night can be a result of poor lightning, that the bicyclists have been inattentive and hit a curb or fixed installation, alcohol may be involved even though it was not mentioned in the accident description and so on. From the results it was seen that alcohol and that the bicyclists have bicycled into something were common accident causes.

The accidents that occurred on the late afternoon/evening was further analysed to see which age ranges that were involved in the accidents. It was seen that the accident cause varied and the involved bicyclist generally was younger than 16 years old and older than 60 years old. However, as mentioned before there is fewer accidents for the ages 25-44 for the bicycle path in general.

5.4.2.2 Location of the accidents

Around 38% of the bicycle path related accidents had an uncertain position of the accidents. Due to this, the statements connected with this analysis should be treated with caution. However, through a manual review of the accident locations it was seen that the majority of the accidents had in most cases stated a street name or/and a district as the location of the accident.

When analysing where the bicycle path design related accidents occur a map over the intensity of the accident was made through an analysis of the accidents in GIS. The analysis did not result in any significant accumulations of accidents. The majority of the accidents occurred relative close to the central parts of Karlstad, but the accidents were quite widely spread. That the majority of the accidents have occurred near the central parts of Karlstad is likely due to that many bicyclists are traveling there and that the bicyclists often moves from one side of the road to the other to reach the destination. A large part of the accidents when the bicyclists have run into a curb or pavement edge is assumed to be a result of bicyclists that crosses a road or intersection. There are many fixed installations in the central parts of Karlstad, which also can explain some of the accidents in the central parts.

Through an overview of the accidents in GIS, it was seen that the majority of the accidents have not occurred on the major bicycle paths in Karlstad. This can be an indication of that the bicycle paths are well designed. However, improper design can be an indirect accident cause when talking about bicycle accidents that may be hard to identify. Examples of this is can be steep and sharp ramps where it happen many operation and maintenance related accidents, that the bicycle path is improperly designed so the bicyclists uses other roads instead and so on.

When the statistics in STRADA was analysed, it was seen that in nearly 50% of the accidents the bicyclist stated that the accident have occurred on a bicycle path. The bicycle path can be both minor and major in this case. That the bicyclist have run into a curb or pavement edge only stood for around 33% of the accidents on a bicycle path. The rest of the accidents are relative evenly distributed over the rest accident causes that was seen in Chapter 4, and in particular Section 4.2.1.2. Some of the accidents that have occurred on a bicycle path have been caused by fixed installations and railway tracks. As mentioned before, the accidents do not necessary occur due to an improper design. A combination with other factors can affect the accidents. However, if one type of fixed installation causes many accidents or if the accidents are in a concentrated area it is most likely some error with the design. No such correlation for Karlstad was found during the analysis. For the accident that not occurred on a bicycle path it was more common that the bicyclists have run into a curb or pavement edge. In as much as 61% of the accidents have the bicyclist stated that they have run into a curb or pavement edge.

5.4.2.3 Influence of other accident causes

Accidents can often be a combination of several accident causes and it is most probably no exception for the bicycle path design related accidents. If there are accidents that was described as a bicycle path design related accident but in reality has another main accident cause was hard to determine. However, during the analysis, it seemed like the design related accidents was in many cases connected to the behaviour of the bicyclist and in some cases interaction with the bicycle.

In many cases when the bicyclist have run into a curb or a pavement edge the bicyclists might have himself/herself to blame. It can be cases when the bicyclist are taking a shortcut and crosses a road on a bad place and hit a curb or pavement edge. If the bicyclist crosses the road in locations, where there is no designed crossing, the curb is likely relative high. Another parameter that can affect the accidents are inattention. If the bicyclists are inattentive, it is easy to hit an edge of mistake because the curb/pavement edge is often close to the bicycle path. It was seen in the analysis that many of the accidents caused by a curb/pavement edge was more common for accidents that occurred on roads and not bicycle paths. On such roads the bicyclists often needs to share the available space with other vehicles. In such areas the bicyclists can be affected by the surrounding traffic, which can result in that the bicyclists, loses control of the bicycle and run into the curb.

However, it can be that improper design is the main cause for many of the curb/pavement edge accidents. Examples of improper design are areas where it is too few locations to cross the road resulting in that the bicyclists needs to pass a quite high curb or pavement edge. Another example of improper design, which may result in a curb/pavement edge accident, are situations where the bicyclists are led to locations where the bicycles paths just ends and becomes a pedestrian walkway. In that situation, the bicyclists might be needed to pass a curb/pavement edge to get to the planned path for the bicyclists.

Accidents that are caused by sharp corners or steep downhills is also examples of accidents that both can be due to an improper design or other factors. Other factors in this case can be slipperiness in combination with the turn, which is relative common but are often defined as an operation and maintenance related accident. Another factor can be the behaviour of the bicyclists. The bicyclists might overestimated their ability to manoeuvre the bicycle resulting in that the bicyclist have to high velocities.

5.4.3 State and behaviour of the bicyclist

The single bicycle accidents that has state and behaviour of the bicyclists as the main accident cause were not so common in Karlstad. Only 11% of the accidents was classified as a state and behaviour related accident. A more detailed analysis of the accidents were performed to see if any interesting findings were found. The analysis was partly based on the result that was presented in Chapter 4, and in particular Section 4.2.1.3.

The number of accident with state and behaviour of the bicyclists as the main accident cause have been relative stable with a slightly decrease from 2009-2013 with the exception of 2011, as mentioned in the result chapter. The year 2011 had an increase in the number of accidents but the number has then continued to decrease during 2012 and 2013. The year with the fewest number of accidents for the analysed period was 2013 when it occurred less than ten accidents. The most accidents occurred in May and followed by July-October. It was also mentioned that the most common sub cause was suspected influence of drugs, lack of balance and inattention of the bicyclists.

The number of accidents have decreased while the number of bicyclists have increased. The number of accidents have decreased all five years except for 2011. The increase of accidents during 2011 was most likely due to accidents with suspected influence of drugs. Almost half of the suspected influence of drugs accidents occurred during 2011. The number of bicyclists have decreased in May under 2012 and 2013 and the majority of the accidents occurred during May. However, this it was judged not to have something to do with the decrease. State and behaviour of the bicyclist related accidents were not as weather sensitive as the operation and maintenance related accidents. Nevertheless, yearly variations of the weather may affect the number of accidents.

The ages of the bicyclist that were involved in the accidents varied, but the most common age ranges were 7-14 and 25-64. That there were relative many accidents for young people may be a result of that young people often play with their bicycles. No interesting findings were found in the analysis of the age distribution of the accidents.

5.4.3.1 Time of the accidents

As mentioned before, the majority of the accidents occurred during the summer months. This was expected because the number of bicyclists are higher during the summer, which was seen in Chapter 2, and in particular Section 2.2.1. Another reason can be that it is more common to take the bicycle to nightclub/pub/restaurant than during the winter months.

The state and behaviour of the bicyclist related accidents were more likely to occur during Thursdays to Sundays. The number of accidents on those two days were relative even. The number of accidents were decreasing from Wednesday to Monday, with the fewest accidents during Mondays. That the state and behaviour related accidents are high on during the weekend when the number of bicyclist are fewer was an interesting finding. A manual review of the accidents that occur on the weekends was performed. The conclusion was that the many accidents on the weekends were likely related to the accidents with a suspected influence of drugs. It is more common to drink alcohol during the weekends compared to a regular weekday.

The distribution of the accidents during an average day was seen in Chapter 4, and in particular Section 4.2.1.3. No significant trend could be seen, but the majority of the accidents occurred between 10:00-21:00. A significant part of the accidents occurred between 21:00-03:00 with a small peak on the night around 02:00-03:00. The peak on the night was likely due to the suspected influence of drugs accidents, which was included in the state and behaviour classification. The accidents do not have the same distribution over the day as for the number of bicyclists. This can be an indication of that the state and behaviour of the bicyclist not are affected so much by the number of bicyclist that are in motion. This seems reasonable considering what the classification includes.

5.4.3.2 Location of the accidents

Around 48% of the state and behaviour of the bicyclist related accidents had an uncertain position of the accidents. The percentage accidents with an uncertain position were very high. This can be connected to health issues or influence of drugs. Due to this, the statements connected with this analysis should be treated with caution. However, through a manual review of the accident locations it was seen that the majority of the accidents had in most cases stated a street name or/and a district as the location of the accident.

When analysing where the state and behaviour of the bicyclists related accidents have occurred a map over the intensity of the accident was made through an analysis of the accidents in GIS. A significant part of the accidents occurred relative close to the central parts of Karlstad. Accumulations were found on some of the major paths to and from the central parts. The rest of the accidents were quite widely spread in Karlstad. The majority of the accidents that occurred near the central parts of Karlstad were suspected influence of drug related accidents. Alcohol was the most common type of drug that was identified during the analysis. That alcohol related accidents were more common for the central parts of Karlstad can be due to that many nightclubs, pubs and restaurants are located there. Several of the accumulations on the major traveling paths in to the central parts can also be related with suspected influence of drug accidents. It can be that the bicyclist have been involved in the accident on the way home from the central parts.

Through an overview of the accidents in GIS, it was seen that the majority of the accidents have not occurred on the major bicycle paths in Karlstad. Around 30% of the accidents have occurred on one of the major bicycle paths. Through an analysis of the accidents that occur on the major bicycle paths it was noticed that there was few suspected influence of drug related accidents on that occurred on the paths. This might be due to that the bicyclists might take the shortest way when bicycling on the night or is affected by drugs. Some indications of this were seen during an ocular analysis of the accidents in GIS.

5.4.3.3 Influence of other accident causes

Accidents can be a combination of several accident causes. It seems like the accidents that were classified as a state and behaviour related accidents were affected less of other factors than other classifications. It seems like the state and behaviour of the bicyclists affects the other accident cause classifications more that they affect it. However, there are certainly cases where the other accident causes affect the accidents classified as a state and behaviour related accident. Some few accidents that were identified in STRADA might have had slipperiness as a supplementary accident cause. Still, it was hard to determine if there are accidents that were described as a state and behaviour related accident but in reality has another main accident cause.

5.4.4 The bicyclist in interaction with the bicycle

The single bicycle accidents that had interaction with the bicycle as the main accident cause were the third most common accident type in Karlstad. Around 13% of the accidents were classified as an interaction with the bicycle related accident. A more detailed analysis of the accidents were performed to see if any interesting findings could be found. The analysis was partly based on the result that was presented in Chapter 4, and in particular Section 4.2.1.4.

It was mentioned in the result chapter that the most common sub causes were that the bicyclists got objects in the wheel of the bicycle, malfunction with the bicycle, that the bicyclist braked to hard that the brakes locked and accidents when the bicyclists gets on and off the bicycle. That objects were stuck in the wheels and when the bicyclists get on and of the bicycle was most likely the bicyclists own responsibility and is therefore hard to prevent. That the bicyclists brakes too hard on the other hand might be connected with other accidents causes, this is more discussed in Chapter 5, and in particular Section 5.4.4.3.

The number of accidents with interaction with the bicycle as the main accident cause have has been relative constant during 2010-2013, as mentioned in the result chapter. The distribution of the accidents over an average year was also shown. It was seen that the majority of the accidents occurred during April-October, with the highest numbers of accidents in August and September.

The number of accidents has been relative constant while the number of bicyclists have increased. This can be an indication of that the bicyclist in interaction with the bicycle was not affected so much of an increase of the number of bicyclists. It seems reasonable due to that many of the interaction with the bicyclists were likely a result of the bicyclists own behaviour, ability and equipment. That the majority of the accidents occur during the summer were expected due to that the number of bicyclists were higher during the summer. When many bicyclists are in motion, it increases the risk that someone handle the bicycle in a wrong way or that someone's bicycle malfunction. It was analysed if more accidents related to malfunction of the bicycle occurs in the spring when many bicyclists take out their bicycle from the last year. This was not the case because the malfunction related accidents was evenly distributed over the months April-October. The bicyclist in interaction with the bicycle related accidents were not as weather sensitive as the operation and maintenance related accidents. Nevertheless, yearly variations of the weather might affect the number of accidents.

The ages of the bicyclist that are involved in the accidents varied, but the most common age ranges were 7-24 and 35-44. The age distribution for the interaction with the bicycle related accident was compared with the one for all single accidents. It was noticed that the percentage of young people (7-24) and old people (75+) was higher for the interaction with the bicycle related accidents compared to the distribution for all single accident. That there were more interaction with the bicycle related accidents for young and old persons can be due to that they are less capable in manoeuvring the bicycle, evaluating different situations and getting on and of the bicycles.

5.4.4.1 Time of the accidents

As mentioned before, the majority of the accidents occurred during the summer months. This was expected because the number of bicyclists were higher during the summer, which was seen in Chapter 2, and in particular Section 2.2.1.

The interaction with the bicycle related accidents were relative evenly spread over the days of the week, but there were some more accidents on Tuesdays and Saturdays. That the interaction with the bicycle related accidents are high on Saturdays while the number of bicyclist on Saturdays are relative low was an interesting finding. A manual review of the accidents that occurred on Saturdays was performed, but no significant correlation between the accidents was found.

From the result chapter, it was seen that a significant part of the accidents occurred on the afternoon around 13:00-19:00. The least accidents occur on the night. That a large part of the accidents occurs in the afternoon can be due to that the number of bicyclists are high. A high number of bicyclists often results in a higher number of accidents. This due to when there are many bicyclists in motion it increases the probability that someone uses the bicycle in a wrong way or that someone's bicycle malfunction. However, the number of bicyclists are high during the morning hours while it have occurred fewer accidents in the morning. It might have something to do with there was relative many young (7-24) and old (75+) persons that have been involved in the accidents. Persons that are older than 75 most likely do not have a job to go to which may result in that older persons bicycle later on the days. Young persons might play with their bicycle when they come home from school, which also might explain why it occurs more accidents on the afternoon than in the morning hours.

5.4.4.2 Location of the accidents

Around 33% of the bicyclist in interaction with the bicycle related accidents had an uncertain position of the accidents. Due to this, the statements connected with this analysis should be treated with caution. However, through a manual review of the accident locations it was seen that the majority of the accidents had in most cases stated a street name or/and a district as the location of the accident.

When analysing where the interaction with the bicycle related accidents occurred a map over the intensity of the accident was made through an analysis of the accidents in GIS. A significant part of the accidents occurred relative close to the central parts of Karlstad and accumulations were found on some locations outside the central parts. Two of the larger accumulations were at Ankersbron Bridge and in Kronoparken centrum. The rest of the accidents are quite widely spread in Karlstad. That a significant part of the accidents have occurred near the central parts of Karlstad can be due to that many bicyclists have been traveling there and that the bicyclists often buy things that are needed to be transported home. That the destination for the bicyclists often are in the central part results in that they need to get on and of the bicycle which also might contribute to the many accidents. The Ankersbron bridge has previous been analysed in Chapter 4, and in particular Section 4.2.1.4.

The accumulation of interaction with the bicycle related accidents by Ankersbron bridge was likely affected by the design of the bridge, the steep downhill and the narrow passage. A result of the three mentioned factors can in many cases result in that the bicyclists suddenly needs to brake, which was one common interaction with the bicycle accident cause. Why the accidents were still defined as an interaction with the bicycle even though it probably was not the main accident cause was due to that it was not mentioned in STRADA.

The accumulation of accidents in Kronoparken centrum can be connected with that two large grocery stores and several restaurants are located in the area. The grocery stores and the restaurants can be the destination for many bicyclists. A result of this is that the bicyclists needs to get on and of the bicycle, which was a common accident cause among the interaction with the bicycle related accidents. Another consequence from the grocery stores can be that the bicyclists needs to transport home groceries that can be stuck in the wheels.

Through an overview of the accidents in GIS, it is seen that the majority of the accidents have not occurred on the major bicycle paths in Karlstad. Around 40% of the accidents have occurred on one of the major bicycle paths. If the statistics in STRADA were analysed, it was a similar amount of accidents that occur on a bicycle path. The bicycle path can be both minor and major in the analysis in STRADA. The accidents on the bicycle paths were quite widely spread in Karlstad, with the exception of Ankersbron Bridge, and no correlation for the accidents was found.

5.4.4.3 Influence of other accident causes

Accidents can be a combination of several accident causes. It seems like the accidents that are classified as an interaction with the bicycle related accidents are less affected by other factors than some other classifications. However, there are certainly cases where other factors affect the accidents classified as an interaction with the bicycle related accident. One example where other parameters most likely have affected the interaction with the bicycle is by Ankersbron Bridge. The ramps to the bridge, a narrow passage and a steep downhill most likely affected the interaction with the bicycle accidents. Other locations with for example sharp corners, steep downhills or with many interaction points with other road users are locations where the bicyclist might need to brake hard, which can result in an accident.

Malfunction with the bicycle might be affected by other parameters/factors such as quality of the road and so on. If the surface is very uneven and contains many holes the probability for malfunction with the bicycle most likely increases.

Other common interaction with the bicycle sub causes, such as object in the wheel, get on and of the bicycle, slipped on the pedal and so on were judged to only be readily affected by other factors.

5.4.5 The bicyclist in interaction with other road users

Interaction with other road users were the least common accident type in Karlstad. Around 7% of the accidents were classified as an interaction with other road users related accident. However, the number of accidents have increased the last two years. A more detailed analyse of the accidents were performed to see if any interesting findings can be found. The analysis was partly based on the result that was presented in Chapter 4, and in particular Section 4.2.1.5.

The accidents were caused by that the bicyclist needed to swerve for other road users. The most common road users that the bicyclist swerved for were other bicyclists, pedestrians and cars. It is important to remember that the bicyclist have not collided with the other road user. If they had collided, it had not been defined as a single bicycle accident. The interaction with other road user accidents might be connected with other accidents causes, which was more discussed in Chapter 5, and in particular Section 5.4.5.3.

The number of accidents decreased from 2009-2011 and increased 2012 and 2013, as mentioned in the result chapter. The distribution of the accidents over an average year was also shown in the result chapter. It was seen that the majority of the accidents occurred during May-October, with the highest numbers of accidents in August.

That the number of accidents increased during 2012 and 2013 was most likely due to the increase in the number of bicyclists in Karlstad. Interaction with other road user related accidents seems to be less weather sensitive than the operation and maintenance related accidents. Nevertheless, yearly variations of the weather might affect the number of accidents.

The ages of the bicyclist that were involved in the interaction with other road user accidents varied, but the most common age ranges were 45-64. However, the percentage of elderly persons that were older than 65 years old were higher compared to the percentage for all single bicycle accidents. This can be due to that older bicyclists have less ability to manoeuvre the bicycle, which in many crowded surroundings can lead to accidents.

5.4.5.1 Time of the accidents

As mentioned before, the majority of the accidents occurred during the summer months. That the interaction with other road user related accidents were highest during the summer months were likely due to that the number of bicyclists and pedestrians were highest during the summer. When there are many bicyclists in motion, the probability for interactions for different road users increases.

The most common days of the week for the interaction with other road user accidents were Mondays, Tuesdays, Saturdays and especially Fridays. That the interaction with other road user related accidents were high on Saturdays even though the number of bicyclist on Saturdays are relative low was an interesting finding. A manual review of the accidents that occurred on Saturdays was performed, but no significant correlation between the accidents was found.

From the result chapter, it was seen that a significant part of the accidents occurred on the afternoon around 15:00-19:00. It was also noticed that there was a peak in the number of accidents in the morning around 07:00-10:00 and one in the middle of the day around 12:00-15:00.

The large part of the accidents that occurred on the afternoon was mainly due to that the bicyclists have swerved for a bicycle or car. The number of road users are most likely high in the morning and afternoon, which can be a reason for the accidents in the afternoon and in the morning. On the morning and afternoon, many road users are likely on their way to/from work/school. A higher number of road users can results in more crowded areas, which affect the accessibility in a negative way for the bicyclists. The accidents that occurred on the morning only occurred on the weekdays. This can be related with that the number of road users on the morning are most likely higher during the weekdays compared to the weekend.

5.4.5.2 Location of the accidents

Around 36% of the bicyclist in interaction with the bicycle related accidents had an uncertain position of the accidents. Due to this, the statements connected with this analysis should be treated with caution. However, through a manual review of the accident locations it was seen that the majority of the accidents had in most cases stated a street name or/and a district as the location of the accident.

When analysing where the interaction with other road user related accidents occurred a map over the intensity of the accident was made through an analysis of the accidents in GIS. That the number of interaction with other road user related accidents were relative few during the analysed period made it hard to see any significant connections for the accidents. However, a significant part of the accidents occurred just outside the central parts of Karlstad. One accumulation of accidents was found by Ankersbron Bridge, the bridge has previous been analysed in Chapter 5, and in particular Section 5.2.2. That the majority of the accidents have occurred near the central parts of Karlstad can be due to that many bicyclists were traveling to and from centrum. More road users are likely increasing the probability for an interaction with other road user accidents.

The accumulation of accidents by Ankersbron Bridge was likely affected by the design of the bridge and the narrow passage. A result of the two mentioned factors can in many cases result in that the bicyclists suddenly needs to swerve for other road users due to that the road has to low capacity. Why the accidents were still defined as an interaction with other road users even though it probably was not the main accident cause was due to that no further information was mentioned in STRADA.

Through an overview of the accidents in GIS, it was seen that the majority of the accidents not occurred on a major bicycle path in Karlstad. Around 45% of the accidents have occurred on one of the major bicycle paths. When the statistics in STRADA was analysed, it was seen that a similar amount of accidents occurred on a bicycle path. The bicycle path could be both minor and major in the analysis in STRADA. The accidents on the bicycle paths were quite widely spread in Karlstad. For the accidents that occurred on a bicycle path it was common that the bicyclists needed to swerve for other bicyclists or pedestrians.

5.4.5.3 Influence of other accident causes

Accidents might often be a combination of several accident causes. It seemed like the interaction with other road user related accidents were less affected that some other classifications such as operation and maintenance. However, there were certainly cases where the other accident causes affected the accidents classified as an interaction with other road user related accident.

Parameters that likely have affected the interaction with other road user related accidents are the road width, behaviour of the bicyclists and other road users, visibility and if the bicyclist have been separated from the other road users.

One example where other parameters most likely affected the interaction with other road users were by Ankersbron bridge. The ramps to the bridge and the narrow passage most likely affected the accidents. This was discussed in Chapter 5, and in particular Section 5.2.2. Other locations with for example narrow passages or with many interaction points with other road users are locations where the bicyclist might need to swerve for other road users.

5.4.6 Accidents with an unknown accident cause

The single bicycle accidents that had an unknown accident cause were the most common type of accident in Karlstad together with the operation and maintenance related accidents. Around 29% of the accidents had an unknown accident cause.

An analysis was hard to perform because the lack of information about the accidents. Still, a more detailed analysis of the accidents were performed to see if any interesting findings could be found. The analysis was partly based on the result that was presented in Chapter 4, and in particular Section 4.2.1.6.

The number of accidents with an unknown accident cause increased 2011 and 2012, as mentioned in the result chapter. The distribution of the accidents over an average year was also shown in the result chapter. It was seen that the majority of the accidents occurred during April-September, with the highest numbers of accidents in June.

That the number of accidents had increased during 2011 and 2012 was most likely due to the increase in the number of bicyclists in Karlstad. Why the accidents not increased during 2013 was hard to say. One potential reason could be that the bicyclists or the hospital has been better in describing the accident cause. Another potential reason can be yearly variations of the weather, which might affect the number of accidents.

The ages of the bicyclist that are involved in the accidents varied, but the most common age ranges were 7-14 and 45-54. However, the percentage of persons that were older than 65 years old and younger than 14 years old were higher compared to the percentage for all single bicycle accidents. Persons that are younger than 6 years old that were particularly overrepresented for the accidents with an unknown accident cause. That there were more young persons than average can be due to that they were less good in describing the accident cause or that the parent only says that their children have fallen with the bicycle.

5.4.6.1 Time of the accidents

As mentioned before, the majority of the accidents occurred during the summer months. That the accidents were highest during the summer months were likely due to that the number of bicyclists and pedestrians are highest during the summer. When there are many bicyclists in motion, the probability for an accident increases.

The accidents with an unknown accident cause were relative evenly spread over the days of the week, but there were some more accidents on Mondays. An analysis of the accidents that occurred on the different days of the week was performed, but no significant correlation between the accidents was found.

From the result chapter, it was seen that the accidents with an unknown accident cause were most common in the middle of the day around 12:00-21:00. A peak in the number of accidents was seen in the night even though the number of bicyclists during the night were relative low. The accidents might be related with poor lightning, drugs such as alcohol and so on. A more detailed analysis of all single bicycle accidents that occur during the night can be found in Chapter 5.6.

That a significant part of the accidents occurred in the afternoon might be explained by the number of bicyclists and other road users are often high during the afternoon. As mentioned before, the number of bicyclist are usually highest in the morning and in the afternoon. That no peak in the number of accidents was seen in the morning around 06:00-09:00 was an interesting finding. The accidents that occur in the morning was analysed further and it was seen that there was few young people that was injured in the morning. It was mentioned before that there was a higher percentage young people injured in an accident with an unknown accident cause compared with all accident. This might explain why there were more accidents in the afternoon than the morning.

5.4.6.2 Location of the accidents

Around 50% of the accidents with an unknown accident cause had an uncertain position of the accidents. Due to this, the statements connected with this analysis should be treated with caution. However, through a manual review of the accident locations it was seen that the majority of the accidents had in most cases stated a street name or/and a district.

When analysing where the accidents with an unknown accident cause occurred, a map over the intensity of the accident was made through an analysis of the accidents in GIS. A significant part of the accidents occurred in or relative close to the central parts of Karlstad. Nevertheless, some accumulations were found on locations outside the central parts. Some of the accumulations seemed to be in residential areas. The rest of the accidents were quite widely spread in Karlstad. That the majority of the accidents have occurred near the central parts of Karlstad can be due to that the number of bicyclists and road users are most likely higher in the central parts. The accumulations in the residential areas can be due to that it is relative many injured young bicyclist and it is likely that they bicycle in such areas.

Through an overview of the accidents in GIS, it was seen that the majority of the accidents have not occurred on the major bicycle paths in Karlstad. Only 25% of the accidents have occurred on one of the major bicycle paths. However, the position of the accidents were often uncertain. The majority of the accidents that have occurred on a major bicycle path have occurred relative close to the central parts in Karlstad. The major bicycle paths just west of the central parts were more prone to accidents compared to the other paths. If the statistics in STRADA were analysed, the amount of accidents that have occurred on a bicycle path are slightly higher. However, the bicycle path can be both minor and major in the analysis in STRADA.

That there were few of the accidents with an unknown accident cause that occurred on the major bicycle paths in Karlstad might be related with that there were many younger persons that got injured, as was mentioned previously. Younger people might bicycle more in residential areas or on smaller bicycle paths compared to older persons.

5.4.6.3 Influence of other accident causes

Accidents might often be a combination of several accident causes. It was very hard to draw any conclusions about this for the accidents with an unknown accident cause due to the lack of information about them. It was believed that the accidents with an unknown accident cause are affected as much as the other classifications.

That many young bicyclists are injured was likely related with the state/behaviour of the bicyclist and interaction with the bicycle. Young persons likely have less manoeuvrability of the bicycle and might play with their bicycle.

5.5 Occurrence of the accidents during the year

The distribution of the single bicycle accident over an average year was presented in Chapter 4, and in particular Section 4.2.3. It was seen that the number of accident was highest during the summer months, May to August. As mentioned before, the number of bicyclists on Sandbäcksgatan and by Sandgrund in Karlstad was also highest during the summer months.

An analysis was performed to see if the correlation between the number of bicyclists and accidents was the same during the whole year. The number of bicyclists was compared to the number of accidents for each month. This in order to analyse which month most accidents per bicyclists occurred. The number of bicyclists were taken from the two monitoring stations at Sandbäcksgatan and by Sandgrund for the years 2011-2013. The probability for an accident was not so interesting to present, due to that the number of bicyclists were relative uncertain. The basis probability was set to the one in December due to that the accident per bicyclist was highest during that month. Each month's probability was compared to the one in December. This was done in order to see relations between different months.

The values for each month were presented as how large part of the value at December the month stood for. The distribution over an average year can be seen in the graph below.

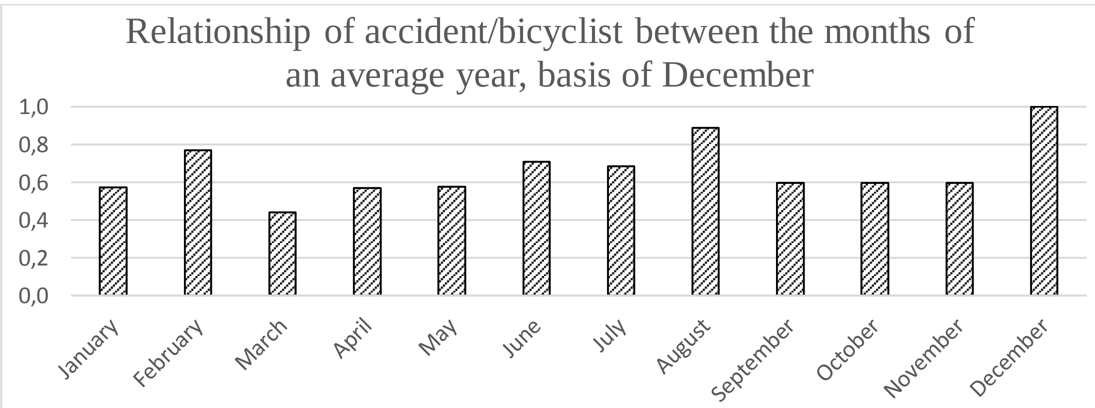

Figure 46 – The figure shows the relationship of accident/bicyclist between the months of the years. Each month's probability was compared to the one in December to see relations between different months. The values for each months were presented as how large part of the value in December it stands for.

It can be seen that the highest probability for an accident per bicyclist was in December. This was because there was relative few bicyclist during the winter compared with the summer but still relative many accidents. The value for December was one due to that the probability was compared with the probability for December. The majority of the accidents during December were operation and maintenance related, especially slipperiness related.

The probability for an accident during August was almost as high as the one in December. The probability for an accident in August was around 90% of the one in December. The number of injured bicyclists were around twice as many in August compared to December, but the number of accidents were also around twice as many. That the accidents per bicyclists almost was the same for the two months was an interesting finding. A common perception is that it is more dangerous to bicycle during the winter due to the ice and snow. From the graph above, it can be seen that this is not entirely true. The most common accident causes in August are all except for operation and maintenance. That the number of single accidents are high during the summer might are likely to the increased number of road users during the summer. March was one of the months with the lowest number of accidents, while the flow was relative high.

The analysis might be sensitive to variations in the number of accidents and bicyclists. It is important to remember that the statistics of the number of bicyclists only were from two of the monitoring stations in Karlstad while the accidents were for the whole city. This can affect the analysis significantly. Any variations in the flow affect the relationship between the probabilities for the months. The number of accidents may not completely correlate to the real life scenario due to that it can be loss in reporting the accidents and as previously mentioned the statistics were only for injured bicyclist that have been either in contact with the police or the emergency hospital.

5.6 Accidents that occur during the night

From the statistics, it was noticed that a relative large part of the single bicycle accidents occurred during the night. It was seen in the distribution of the bicycle flow on Sandbäcksgatan and by Sandgrund that there was a quite low flow during the night. Due to this, the accidents that occurred during the night was further analysed to improve the knowledge about the accidents that occurred during the night.

That the flow was low during the night can be a result of the placement of the monitoring stations. Due to this, when analysing the accidents that occurred during the night, the flow of all six monitoring stations were used. However, there were only data for the last year for all six monitoring stations. The distribution of the bicycle flow over the day when using all six monitoring stations was very similar to the one with only two monitoring stations. The number of bicyclists were a little bit higher when using all six monitoring stations, but the increase was insignificant and it did not change the distribution over the day.

The number of bicyclists was compared to the number of accidents for each hour to analyse when most accidents per bicyclists occurs. The probability for an accident was not so interesting to present, due to that the number of bicyclists were relative uncertain. The basis probability was set to the one at 02:30 due to that it had the highest probability. Each hours' probability was compared to the one at 02:30 to see relations between the different hours. The values for each hour were presented as how large part of the value at 02:30 the hour stood for. The distribution over an average day can be seen in the graph below.

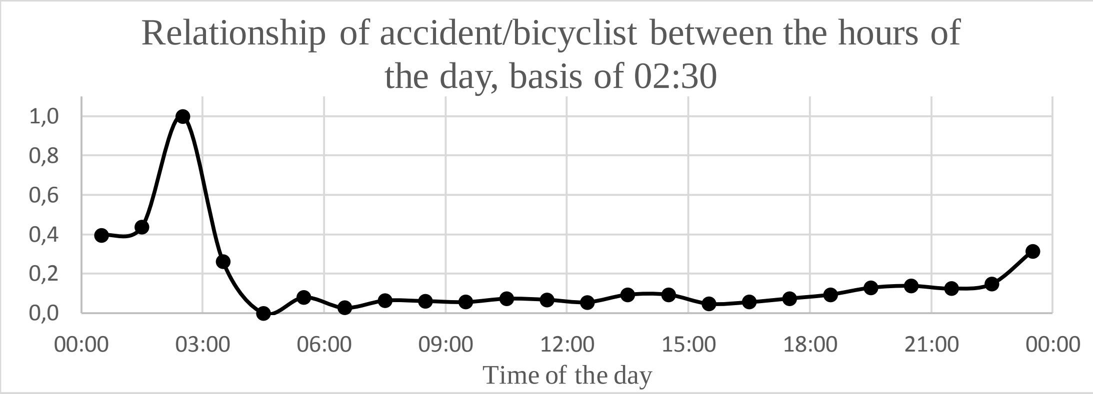

Figure 47 – The figure shows the relationship of accident/bicyclist between the hours of the day. Each hours' probability was compared to the one at 02:30 to see relations between different hours. The values for each hour were presented as how large part of the value at 02:30 the hour stands for.

It can be seen that the highest probability for an accident per bicyclist is at the night around 02:00-03:00. This because there were few bicyclist during the night compared to the day while relative many accident. The value was one due to that the probability for an accident was compared with the probability for 02:30. Most of the accidents that occurred during the night was located quite central in Karlstad. A result of that could be that the monitoring stations underestimate the number of bicyclists during the night. If the number of bicyclists during the night was underestimated, the results in the figure above do not correlate with the real life situation. To see how sensitive the analysis was, the number of bicyclists during the night was increase with 50%. However, the increase did not significantly affect the analysis.

A further analysis of the accidents during the night was performed due to that the probability for a single bicycle accident per bicyclist were very high on the night. Accidents that have occurred between 23:00-04:00 were included in the analysis, due to the higher probabilities for this times that was noticed in the figure above.

From 2009 to 2013, 84 single bicycle accidents have occurred between 23:00-04:00. Twelve accidents have occurred at an unknown time. That results in that the accidents during the night stood for around 15% of all accidents. As mentioned before, most of the accidents occurred central in Karlstad. Through an analysis of the accidents in GIS, a map over the intensity of the accident was made. The intensity analysis was performed with to see where there have happen accidents within a distance of 300m from each other. Several locations were relative uncertain and due to that, the distance of 300m was chosen.

The result can be seen in the figure below. The black lines are major bicycle paths in Karlstad and the intensity scale goes from black to red, where red were areas with a high intensity of accidents.

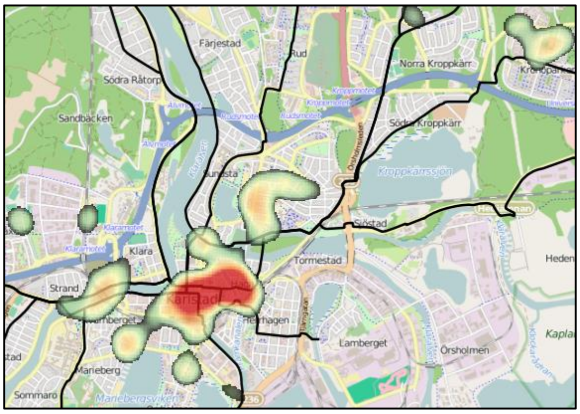

Figure 48 – The figure shows a map over the intensity of the single bicycle accidents that have occurred during the night in Karlstad from 2009-2013. The intensity scale goes from black to red, where red were areas with a high intensity of accidents.

It can be seen that the majority of the accidents occurred in the central parts of Karlstad. The red areas in the figure covers the central parts of Karlstad. Some more areas that have a relative high accident intensity can be seen in the figure. That the highest number of accidents were in the central parts could be due to that there are probably more bicyclists in the central parts of the city during the night compared to surrounding areas.

A further analysis of the accidents that was performed was to analyse which accident causes that was most common during the night. The accident causes were manually identified and the results can be seen in the bar chart below.

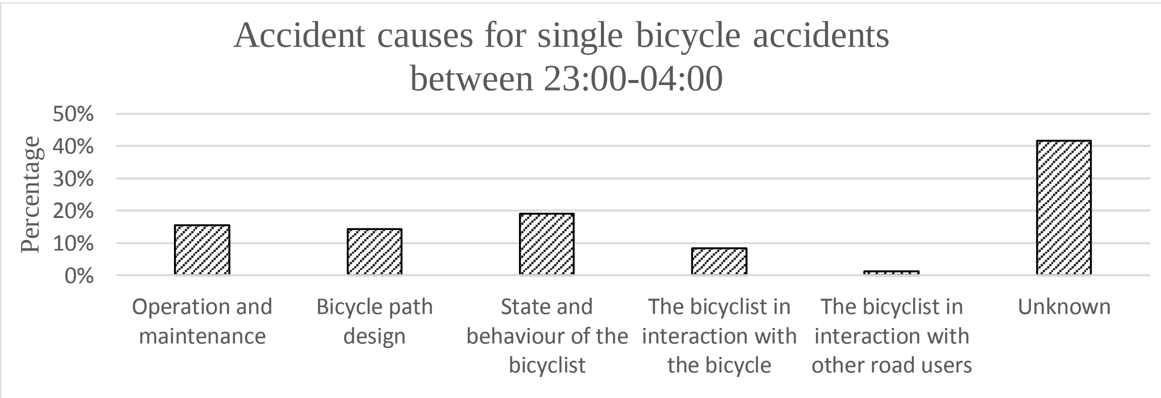

Figure 49 – The bar chart shows the distribution between different accident causes in single bicycle accidents between 23:00-04:00.

It can be seen that the most common accidents cause for the single bicycle accidents that occurred during the night was other/unknown that stood for around 40% of the accidents. The operation and maintenance related accidents only stood for around 15% of the accidents. This could be compared with 29% as it stood for of all single bicycle accidents. This means that it was relative few operation and maintenance related accidents during the night. The bicyclist in interaction with other road users stands for an insignificant part of the accidents during the night. This were expected do to that the number of bicyclists were few during the night.

The ages of the injured bicyclists was analysed to see which ages that were involved in most accidents during the night. The distribution over the age ranges can be seen in the bar chart below.

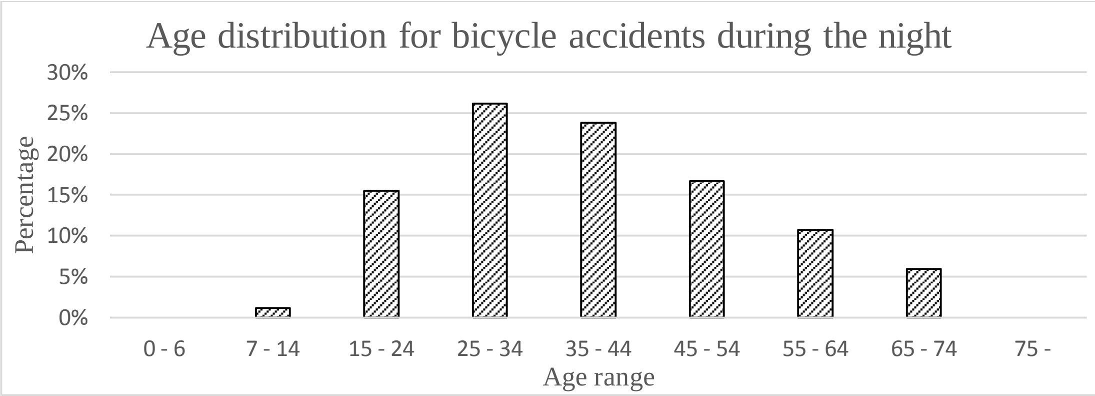

Figure 50 – The figure shows the age distribution for the bicyclists that have been injured during the night in Karlstad from 2009-2013.

It can be seen that it was most common for ages 25-44 to get injured during the night, which stands for around 50% of all injured bicyclists. The age distribution differs to the one for the singe bicycle accidents in general that was mentioned in Chapter 4, and in particular Section 4.2.2. It was more common that men were injured during the night than women, 65% of the injured were men and 35% were women.

The days of the week, of which the bicyclists was injured, was analysed to see the distribution between the days for accidents during the night. The distribution over the days of the week can be seen in the bar chart below.

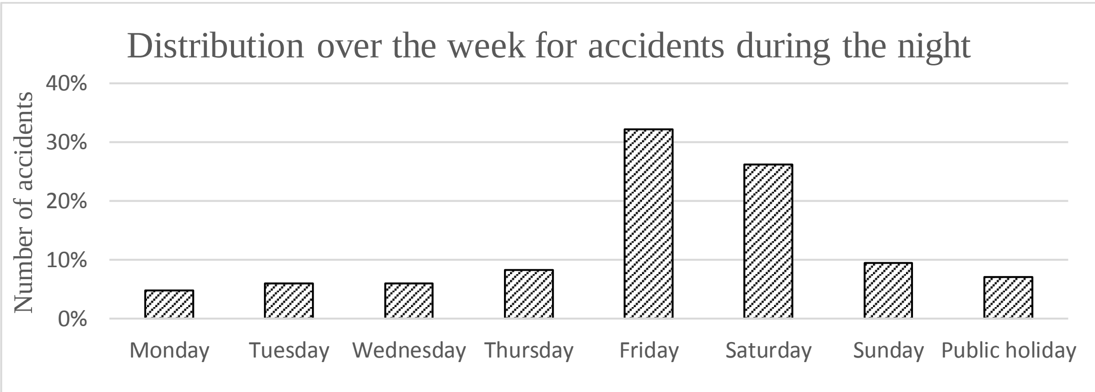

Figure 51 – The figure shows the distribution over the week of the single bicycle accidents that have occurred during the night in Karlstad from 2009-2013.

It can be seen that the majority of the single bicycle accidents have occurred on weekends. Nearly 60% of the accidents that have occurred the night Friday/Saturday or Saturday/Sunday. This was expected thus the number of bicyclists during the night are most likely higher on weekends and holidays. However, a significant part of the accidents has occurred from Sunday-Thursday. Some of the accidents during the weekdays might be explained by that during the summer or during vacations, more people most likely bicycles during the night for all days of the week.

5.7 Bicyclists that needed institutional care

To see which age group that were more likely to be hospitalized the bicyclists that needed institutional care have been separated for different age groups. Institutional care means that the bicyclists have been admitted to the hospital more than one day. The distribution was expressed as the percentage of bicyclists in the different age rages of the total number bicyclist that needed institutional care. The result can be seen in the bar chart below.

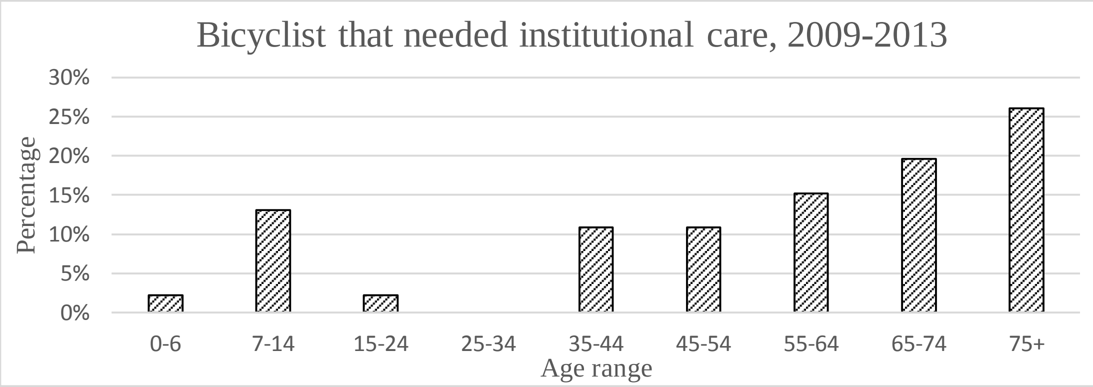

Figure 52 – The bar chart shows bicyclists the distribution for different age ranges that have been involved in a single accident and needed institutional care. The distribution was expressed as the percentage of bicyclists in the different age rages of the total number bicyclist that needed institutional care.

It was more likely for elderly people to need institutional care due to injuries suffered from a single bicycle accident. Around half of the bicyclists that needed institutional care were older than 65 years. For bicyclists younger than 34 years old it was uncommon with institutional care, except for the bicyclists between 7-14 years old. 26% of the persons of needed institutional care suffered from a concussive injury.

The accidents in STRADA was analysed to see the percentage for each age range that needed institutional care. The result from the analysis can be seen in the bar chart below.

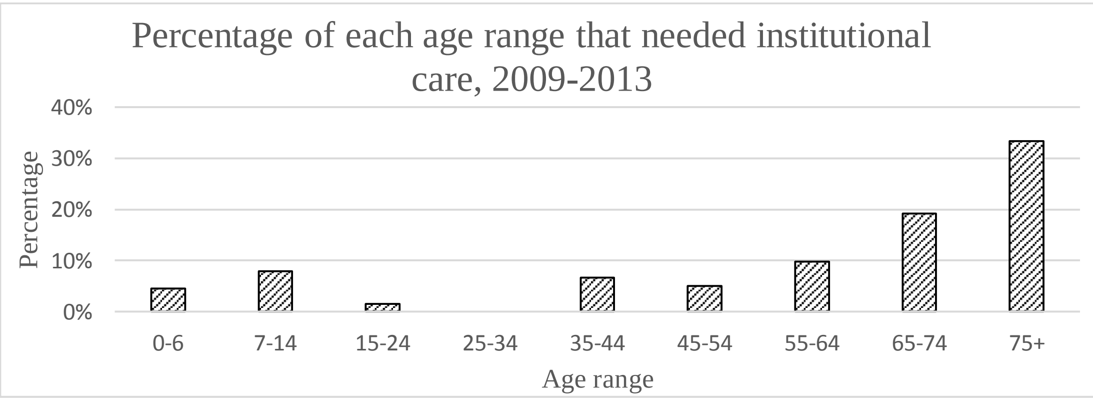

Figure 53 – The figure shows the percentage of each age range that have been admitted to the hospital more than one day due to a single bicycle accident.

It can be seen in the table above that single bicycle accidents are more dangerous for elderly persons. More than 30% of the injured bicyclist older than 75 years old have been admitted to the hospital more than one day due to a single bicycle accident. The accident cause for the different age ranges was seen in Chapter 4, and in particular

Section 4.2.2. For the age range 75+ the most common accident causes was the bicyclist in interaction with the bicycle and accidents with an unknown accident cause. The bicyclist in interaction with other road users were also relative common compared with the other age ranges. That older persons is more likely to need institutional care than younger is most likely due to that older persons are more fragile and the probability to break a bone are higher.

It was also noticed that persons older than 65 years old were overrepresented in the number of severe accidents (ISS > 8). They stand for around half of all severe accidents in Karlstad. It was very few of the severely injured bicyclists that have used a helmet during the accident occasion, for all age ranges.

The number of days that the bicyclists needed hospital care was presented in a cumulative diagram. A cumulative diagram is a diagram that presents the amount of the bicyclists that needed a certain number of hospital care or less. The result can be seen in the graph below.

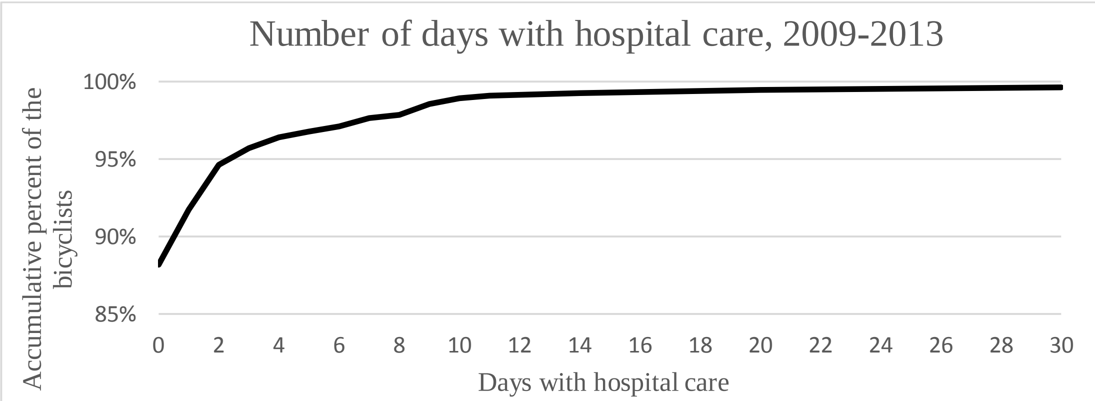

Figure 54 – The graph is a cumulative diagram over the number of days with hospital care for bicyclists involved in a single bicycle accident in Karlstad, 2009-2013.

It can be seen that 88% of the bicyclists involved in a single accident needed none day with hospital care. Around 92% of the bicyclists needed one or less day with hospital care. A very small part of the injured bicyclists needed more than 30 days with hospital care.

6 Discussion

The discussion includes a discussion about the single bicycle accidents in general, about the analysis and findings in the analysis, measures to improve the safety for bicyclists, STRADA, sources of errors and reliability of the result/analysis.

6.1 Single bicycle accidents

The single bicycle accidents in Karlstad stood for around 75% of all reported bicycle accidents. It was either the police or the emergency hospital reported the accidents. The single bicycle accidents in Sweden were around 70-80% of all bicycle accidents. It was seen that Karlstad was in the middle of the general values for Sweden. However, it was only the accidents that were reported to STRADA by the police or hospitals that was included. In reality, the single accidents likely stands for more than 75% of all bicycle accidents in Karlstad. A large part of the single bicycle accidents is often minor. A result of that can be that many single bicycle accidents not are reported to STRADA. The single bicycle accidents are in that case underestimated. The accidents between bicyclists and motor vehicles, which stands for 15% of the accidents in Karlstad, often are more severe compared to single accidents. The number of unreported accidents between bicyclists and cars are most likely less than for the single bicycle accidents.

In the analysis the number of single bicycle accidents per million bicycle trips was calculated. It was seen that Karlstad was in the middle of the statistics for Sweden in general, which was the case in a report by Spolander as well. From the results, it was seen that the percentage of single bicycle accidents and the distribution between the accident causes were relatively similar to the ones for Sweden in general. It feels like Karlstad is a quite typical city when it comes to single bicycle accidents.

The costs for the society that bicycle accidents and injured bicyclists led to was mentioned in Chapter 2, and in particular Section 2.5. No calculations have been performed to see the effects on the costs for the society that the bicycle accidents result in. However, an accident results in quite high cost, which is important to remember when talking about traffic safety for bicyclists and planning preventive measures.

6.2 Analysis of the single accidents

The analysis was based on the statistics in STRADA because it was the best available information source. The analysis was performed with Excel and GIS as supporting programs. The analysis of the areas prone to accidents in GIS was performed with help of a built in function. To check the built in function another way to find the areas prone to accidents was used as well. The other method was manually created in GIS. The result from the two different methods was similar which strengthens the result over the areas prone to accidents.

The accident causes, the accidents that occurred during the night and the injuries that bicyclists have sustained were separately discussed below.

6.2.1 Accident causes for single bicycle accidents

The distribution between the six accident cause classifications in Karlstad was similar to Sweden in general. The main classifications for the accident causes were discussed separately in this chapter. The discussion was based on the results and analysis.

It is important to remember, that it was most probably several factors in combination that have caused the single bicycle accidents. It can be a chain of events where different factors result in the accidents.

6.2.1.1 Operation and maintenance

Operation and maintenance as the main accident cause were the most common accident cause in Karlstad for single bicycle accidents. It was the second most common when it came to severe accidents. The most common sub causes for the accidents was slipperiness due to ice/snow, sand and leafs. Other sub causes are loose objects on the bicycle path and uneven surfaces/holes. Due to this, it is important with proper operation and maintenance, especially during the winter and spring. The importance of good operation and maintenance of the bicycle paths in the city was seen in the report. For the safety of the bicyclists, it is important that the responsible road authorities become aware of the importance of proper operation and maintenance of bicycle paths. Some of the accidents was, as mentioned, due to loose objects on the bicycle path. These types of accidents are relatively easily eliminated with proper operation and maintenance. However, good methods to identify flaws in the operation and maintenance are important because the earlier a flaw is identified the earlier it can be remedied.

From the analysis, it was seen that a significant part of the accident occurred during the morning hours. This peak in the morning hours was especially due to slipperiness accidents on ice/snow. If it is due to that the snow clearance start too late so the bicycle paths still are icy or snowy when the bicycle commuters travel in the morning or if the bicyclists are more stressed in the morning is hard to say. An analysis of how large effect stress have on the operation and maintenance related accidents in the morning would be very interesting. For Karlstad it can be interesting to analyse where the “morning accidents” have occurred to see if the snow clearance needs to start earlier in some area. Nevertheless, it is very important that the snow clearance start in time. In many cases the snow clearance capacity is limited which result in that some bicycle paths may be prioritized.

Bicyclists are more sensitive to flaws in the operation and maintenance than for example cars. It is important to have this in mind when planning the design and operation/maintenance for the bicycle paths. However, the bicyclists also have a responsibility for the traffic safety for bicyclists. The bicyclists need to follow the traffic rules, use proper equipment and adjust their cycling in relation to the weather and different situations that may arise during the journey.

6.2.1.2 Bicycle path design

A good design of the bicycle paths are important so the number of bicyclists can increase while the safety for the bicyclists not are reduced. A good design is a design that is adapted to bicyclists' needs with a sufficient capacity on the paths and intersections, resulting in a good accessibility. Important when it comes to the design is that the design is understandable for the bicyclists. An unclear design likely increase the probability for accidents and that the bicyclists do not follow the traffic rules. Some of the design related accidents might be relative easily eliminated, for example poor guidance for the bicyclists and so on. Due to this, good methods to identify flaws in the design are important because the earlier a flaw is identified the earlier it can be remedied.

The most common sub cause that was identified in STRADA was that the bicyclists have run into fixed objects, especially curbs/pavement edges. That many bicyclists run into curbs/pavement edges is important to have in mind when designing for the bicycle traffic. This is so the designer thinks about the bevelling of the curbs, to have stable support strips, smooth transition between the road and the surroundings and so on.

Many bicyclists had run into fixed installations, barriers and railway tracks. Barriers and some other objects is in some cases used so cars and other vehicles not can use the bicycle paths. Other solutions that are not so harmful for bicyclists should maybe be used instead of the old ones and the placement of such obstacles should be well planned. Fixed installations can be numerous kinds of things, such as bus shelters, rails and so on. Barriers, fixed installations and railway tracks should be clearly marked, with for example reflective markings, so the different objects are easily seen.

Bicyclists are unprotected road users and are more sensitive to flaws in the design compared with protected road users such as cars. It is important to have this in mind when planning the design of the bicycle paths. However, the bicyclists does also have a responsibility for safe cycling. The bicyclists need to follow the traffic rules, use proper equipment and adjust their cycling in relation to the weather and different situations that may arise during the journey.

6.2.1.3 State and behaviour of the bicyclist

State and behaviour of the bicyclists related accidents stood for around 11% of the single bicycle accidents in Karlstad. To decrease the number of accidents it is important to try to affect the state and behaviour of the bicyclists. Information about bicycle accidents and a proper equipment can be examples of methods to decrease the number of accidents. However, the bicyclist have a big responsible when it comes to state and behaviour when bicycling. The road authorities should provide good conditions for bicycling but it is up to the bicyclists to use the bicycle properly, use proper equipment, bicycle safely and follow the traffic rules and so on.

The most common sub cause that was identified in STRADA was suspected influence of drugs during the accident. The most common drug was alcohol. It is important that the bicyclists have knowledge about the risks with bicycle under the influence of alcohol.

It was seen in the data from STRADA that usage of mobile phone was uncommon as a main accident cause. In some few cases in Karlstad was the mobile phone identified as the main accident cause. If it is due to it have occurred few accidents when the mobile phone is the main accident cause, that accidents have insufficient accident description or that the bicyclist not wanted to say it was because the mobile phone. Nevertheless, the feeling is that more and more people are using their mobile phone while bicycling. It would be interesting how the trend for the mobile phone related accidents would be in the future.

6.2.1.4 The bicyclist in interaction with the bicycle

The most common sub cause that was identified in STRADA was that objects have been stuck in the wheel so the bicycle have suddenly stopped. Common objects was bags, clothes, passenger's and the bicyclist's foot. It is important that the bicyclists transport objects on the bicycle properly so they do not get into the wheel and that the bicyclists wear proper clothes.

Another quite common sub cause was that the bicyclists have been injured when getting on and off the bicycle. It was mainly older persons that have been involved in such accidents, especially women. Two potential measures to decrease some of this type of accidents are to get older persons to use a lower bicycle, to use a tricycle or a women's bicycle instead of a men's bicycle. A women's bicycle have a lower frame and is easier getting on and off it. A tricycle is much more stable than a regular bicycle. On the other hand, a tricycle is more space demanding than a regular bicycle.

Several accidents occurred due to malfunction of the bicycle thus is important for the bicyclists to maintain their bicycle. It could be an idea to regularly inform and remind the population in Karlstad to maintain their bicycle. Bicycles need maintenance just like other vehicles.

A part of the accidents had occurred due to that the bicyclists have braked hard so the brakes of the bicycle have been locked. That the bicyclists have braked hard can be due the bicyclists have used the brakes improperly, faults in the design, other road users and so on. It is important to design bicycle paths with good visibility to decrease the sudden stops.

The bicyclists have a responsible when it comes to the bicyclists in interaction with the bicycle related accidents. The road authorities should provide good conditions for bicycling but it is up to the bicyclists to use the bicycle proper, use proper equipment, bicycle safely, transport objects properly and follow the traffic rules and so on.

6.2.1.5 The bicyclist in interaction with other road users

It is important that the bicycle paths have sufficient capacity for the bicyclists. It is especially important in areas where the area is shared between pedestrians and bicyclists. Sufficient capacity on the paths is important if the bicycle traffic increases in the future. Separated lanes for the bicyclists and the pedestrians are preferable. Congestion on the paths can lead to stress and irritation, which can increase the probability for a bicycle accident.

Visibility conditions is also important when talking about interaction with other road users related accidents. The probability for an accident is most likely lowered if the visibility is good for the users of the road.

From the analysis of the accidents in STRADA, it was seen that a part of the bicyclists had swerved (or touched) doors of cars that have been parked along the roads. Vehicles that are parked along roads is an issue for the bicyclists' safety. This is important to have in mind when planning the bicycle paths in the city and try to lead a major part of the bicyclists to roads that not have vehicles parked along the roads.

The interaction between bicyclists and pedestrians in Karlstad was frequently discussed in subject letters in the local newspaper in Karlstad during April 2015. The bicyclists thinks that the pedestrians walks on the bicycle paths while the pedestrians thinks that the bicyclists bicycle on the walkways. Site visits in the central parts of Karlstad was performed to study the situation. It was perceived that it was both bicyclists and pedestrians that made mistakes. It is important to use proper signs and have clear markings on the bicycle paths.

The bicyclists have a responsibility when it comes to the bicyclists in interaction with other road user related accidents. The road authorities should provide good conditions for bicycling but it is up to the bicyclists to use the bicycle proper, use proper equipment, bicycle safely, respect other road users and follow the traffic rules and so on.

6.2.1.6 Accidents with an unknown accident cause

The accidents with an unknown accident cause was hard to analyse due to the insufficient accident description and that a large part of the accidents had an uncertain location. However, it was seen in the result that few accidents occurred in the morning while more occurred in the afternoon and it was also a peak in the number of accidents during the night. This was discussed in the analysis part.

That many accidents had an unknown accident cause can be due to several different reasons. Examples of potential reasons are that the bicyclists do not remember the accident situation, that the bicyclist do not want to give a more detailed description and so on. It is important to inform the emergency hospitals and the police of the importance of a well described accident scenario so future accidents can be prevented.

6.2.2 Accidents that occur during the night

An interesting finding was that the number of accidents during the night was high compared with the number of bicyclists that was registered by the monitoring stations. That the relative dangerousness was higher on the night compared to the day was expected but it was surprisingly high. Because of that, it was further analysed. The placement of the monitoring stations most likely affected the result. However, a small sensitivity analysis was performed as the flow was increased with 50% during the night. The effect of that was insignificant.

The accident cause that was most common was unknown (≈ 40%), followed by the state and behaviour of the bicyclist (≈ 20%). That the accidents with an unknown cause was most common are hard to say. It might be connected to alcohol, but it is impossible to say. The state and behaviour related accidents is can be connected with alcohol, sleepiness, inattention and so on. It was seen that the most accidents during the night occurred quite central in Karlstad. This is likely due to that more people travels there during the night compared with areas further away from the central parts.

Due to that, many bicyclists are injured during the night, it might be important to encourage people to use proper equipment, bicycle safely and to bicycle carefully under the influence of drugs or suggest that they do not bicycle under the influence of drugs and so on. Especially for middle-aged people 25-54 because they are overrepresented in the accident statistics.

6.2.3 Injuries due to single bicycle accidents

It was seen in the results and the analysis that it was mainly older persons that needed institutional care. A large part of the older persons that have been involved in a single bicycle accident needed institutional care. This was expected due to that older persons are often more fragile than younger persons. It is very important to have this in mind when planning the bicycle paths so they are accessible and suitable for all age ranges, especially older persons. Some potential measures to decrease or mitigate the accident where older persons have been involved can be to use a lower bicycles, a women's bicycle instead of a men's bicycle or a tricycle. A women's bicycle have a lower frame and it is easier getting on and off it and a lower bicycle result in a lower fall in case of an accident. A tricycle is much more stable than a regular bicycle.

The most common type of injury was whole area followed by skeletal/fracture, wound and crush/clamping. The most common body parts to injure was the face/head followed by shoulders and knees. It is important to know which injuries that are the most common so they can be prevented. To mitigate the injuries it is important that the bicyclists uses proper equipment, bicycle safe, bicycle in proper velocities and respect the other road users. Another approach to mitigate the accidents can be to promote lower bicycles, women bicycles and tricycles.

6.3 Measures to improve the safety for bicyclists in Karlstad

The municipality of Karlstad have a great responsibility when it comes to traffic safety for bicyclists. However, it is most likely hard to remove all types of accidents such as alcohol related. Nevertheless, the municipality can most likely affect several different type of accidents that occur in the city. It is a matter of money, time, space and willingness.

To improve the conditions and the environment for the bicyclists, bicyclists needs to be taken into consideration when planning/designing infrastructure in the future. The initiatives for bicycling and bicyclists should preferable be long-term. Some measures that possibly can increase the traffic safety for the bicyclists in Karlstad are mentioned below.

To further analyse and work with areas that were prone to accidents. A large part of the accidents occurred in the central parts, which makes it an important area to work with. Nevertheless, several accumulations with accidents that are located a little bit further out from the central part. Some of them have been mentioned in the report but not all of them. It can be a good thing to see if the traffic safety for bicyclists easily can be increased in the areas with accumulations. The increased traffic safety can be reached in different way but three steps that are useful are: Remove as many risks for bicyclists as possible, think and work in new or different ways (other methods and so on) and reduce the remaining risks.

A proper and well-planned operation and maintenance of the bicycle paths in Karlstad is important for the traffic safety. As mentioned before, operation and maintenance is the most common main accident cause for single bicycle accidents.

Well planned/designed bicycle paths and areas for bicyclist so it is clear where to bicycle and not. Additional information to the inhabitants in the city can be a complementary measure to the planning/designing phase. Good visibility is important in corners so the bicyclist can see flaws in the design, the state of the road and if the bicyclist is going to interact with another road users. To separate the bicyclists from other road users can be a good preventive measure to decrease the number accidents where there are sufficient space.

6.4 STRADA

STRADA is a very useful tool for municipalities, other road authorities and researches in Sweden. Municipalities and road authorities can use the statistics from STRADA as a complementary tool during planning phases. Sweden have in STRADA a large information source concerning traffic accidents. This in combination with that it is internet based and quite user-friendly makes it a very useful tool.

As mentioned before, STRADA have two information sources, the police and the emergency hospitals. It is important that the registration of accidents from these two sources have good routines and that the accidents are reported continuously. The police have had some issues with their routines resulting in that deficient reporting. It is important to remember that it most likely is a relatively large number of unreported accidents, especially for minor accidents that never encounters the police or emergency hospitals. However, the accidents reported to the database entails a great opportunity to get a good overview of accidents that happen in Sweden.

It is important to have knowledge about the local emergency hospitals and their registration to STRADA. This due to that the hospitals joined the registration different years and there are always a delay between the time of the accident and the registration. In some cases, it can be problems with the registration. The STRADA user can contact the local STRADA-coordinator because he or she have information about such subjects.

The Swedish Transport Agency have released a new version of STRADA in May 2015. The old version was quite outdated and it will be interesting to try the new version. One can only hope that the new version increases the use of STRADA

6.5 Sources of errors

The statistics in STRADA can in several views be a potential error source. The accident reporting to STRADA can be deficient in some situations, with a part unreported accidents and accidents with uncertain accident description/information. It have occurred one known fatal accident in Karlstad that is not included in the statistics. This is an example of the loss of accidents in the statistics. It is important to remember that it is only the accidents where a person have visited an emergency hospital that is reported from the healthcare. However, although there can be some issues with STRADA it is still a very useful tool.

The classifications that have been used when analysing the accidents have most likely affected the results. The question is how the result would have been if other classifications had been used. The chosen classifications was used due to that previous research have used similar classifications. The manual interpretation of the accident descriptions have most likely also affected the results. It was hard to determine the main accident cause in several of the accidents and the result might have differed a bit if another person had analysed the accident descriptions.

Rebuilding/new constructions and changed routines during the analysed period can also have affected the results. It can result in a changed environment for the bicyclists, which in turn may increase/decrease the number of accidents. This may affect both the distribution between the accident causes and areas that is prone to accidents. In the intensity analysis, a location that was prone to accidents was found quite central in Karlstad. This location was not mentioned in the analysis because it was been rebuilt in 2012-2013.

6.6 Reliability of the result/analysis

The analysis have been performed for a five year period in Karlstad, 2009-2013. The question is if five years are a sufficient period to get statistical reliable results. It have occurred around 722 reported bicycle accidents and 558 single bicycle accidents in Karlstad during the period. If another period was used the results have most likely been effected. The number of accidents were judged to be sufficient to provide reliable result.

Some of the classifications had relative few accidents within the analysed period. These were bicycle path design, state and behaviour of the bicyclist, interaction with the bicycle and especially interaction with other road users. However, the number of accidents are judged sufficient to describe the accident situation in Karlstad. As mentioned before, if a longer time period was chosen it might not correspond to the situation that are today.

A significant part of the accidents had an uncertain location in STRADA. However, through a manual review of the accident locations it was seen that the majority of the accidents had in most cases stated a street name or/and a district. Why the positions had been stated to be uncertain despite the fact that a street or district have been stated is hard to say. Nevertheless, this was judged to not affect the result and analysis significantly.

7 Conclusion

Karlstad is a city that appears to be quite similar to Sweden in general when it comes to bicycle- and single bicycle accidents. Karlstad was in the middle in the statistics when it came to injured bicyclists per million bicycle trips. The accident causes for the single bicycle accidents followed previous studies over bicycle accidents in Sweden.

STRADA was used as an information source for the bicycle accidents. STRADA can be a very useful tool for municipalities and other road authorities in Sweden. Municipalities and road authorities can use the statistics from STRADA as a complementary tool during planning phases. Sweden have in STRADA a large information source concerning traffic accidents.

Proper, well-planned and well-executed operation and maintenance of bicycle paths are important when it comes to traffic safety for bicyclists. This due to that operation and maintenance were the most common main accident cause for single bicycle accidents in Karlstad. It was especially slipperiness related accidents due to ice, snow and sand that contributed to the operation and maintenance related accidents. A large part of the operation and maintenance related accidents have occurred during the morning hours in the winter months. This is important to remember when planning the operation and maintenance of the roads/paths so the snow clearance and de-icing starts in time. Good and well-planned snow clearance, de-icing during the winter and sweeping of the sand in the spring is measures that can decrease the number of single bicycle accidents. It is important that the snow clearance/de-icing start in time so the paths are cleared before all bicyclist are travelling to work, school and so on.

That a significant part of the accidents were found in the central parts of Karlstad is important to remember. It is therefore extra important with the design of the bicycle paths and areas for bicyclists in centrum. However, in the central parts it is often lack of space, which might lead to that the quality of the design is affected. Some of the bridges in Karlstad was also quite prone to accidents. It is therefore important to have bicyclists in mind when designing bridges, especially the ramps and connections. The ramps should preferable be as smooth as possible and it should be sufficient space for the different road users.

Several different measures can be used to decrease the single bicycle accidents in Karlstad. Some measures was mentioned in the previous part. Other measures that not are connected to operation and maintenance and have been discussed in the report are to have low curbs/pavement edges in areas where many bicyclists are traveling, well-marked/placed fixed installations, good clearance where to bicycle and not, separated bicycle paths and encourage the inhabitants to maintain their bicycle.

A significant part of the bicyclists that have been severe injured or needed institutional care was older persons. This is important to have in mind when planning and designing for bicyclists. If older persons use lower bicycles, women’s bicycles or a tricycle, it might decrease the number of accidents and the severity of them. A lower bicycle means a lower fall in case of an accident. A women’s bicycle are easier to get on and off compared to a men’s bicycle. Getting on and off the bicycle was a quite common accident cause for older persons.

It is important to remember that bicycle accidents result in costs for the society. Increased measures to decrease or mitigate the accidents might lead to a profitability for the society.

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