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Bicycle accidents: An analysis of the causes of single bicycle accidents in Stockholm

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INSTITUTIONEN FÖR GEOVETENSKAPER

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Content

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Abstract: Bicycling has many advantages. For example, it emits less noise compared to motor vehicles, it is environmentally friendly, and bicycling, as a means of transport, gives people exercise.
To encourage bicycling in Sweden, the Swedish government has promoted policies and proposals on national and local levels.
At the same time, several pieces of research on bicycle use in Sweden show that more people are bicycling now than 60 years ago.
STRADA's (Swedish Traffic Accident Data Acquisition) reports also show that most people who are severely injured in traffic are bicyclists, and that most bicycle accidents occur in urban and metropolitan areas.

Stockholm is a European city with a growing population. At the end of 2013 the population were 897 700 and it is predicted to grow by 25 % by 2030. The municipality of Stockholm is working on investment projects for bicyclists with the aim to increase accessibility and road safety such as special road safety measures at intersections that often aim at improving road conditions for both pedestrians and bicyclists, and better maintenance of bicycle paths, both in summers and winters. Critics and different debate articles about bicyclists` safety and accessibility point out that the investments that Stockholm municipality is making are not enough for meeting the growing population, especially for bicyclists.

The aim of this study is to analyse the causes of bicycle accidents in the city of Stockholm. To help answer the research questions stated below, statistics on bicycle accidents were extracted in Excel from Strada and compiled in Excel using the Excel tool PivotTable and Analysis Tool Pak. The questions investigated in the thesis are as follows: when and where are bicyclists most likely to suffer an accident, why does the accident occur, and what causes are behind bicycle accidents at the chosen place of investigation? Five categorisations on the causes of single bicycle accidents were used and these were: operations and maintenance, road design, bicycle interactions, cyclists' behaviour and conditions, and interaction with other road users.

In addition to the above, a semi-structural qualitative interview was conducted with bicyclists who bicycle in or along the report's area of investigation. The results of this report show that single bicycle accidents in the investigated area have increased between 2010 and 2016, and that many bicyclists are not satisfied with the bicycle infrastructure in Stockholm.

Keywords: Bicycle accident, single-bicycle-accident, safety, sustainable development, Stockholm, STRADA

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Summary: The study is based on single bicycle accidents which occurred in Stockholm inner city during 2010–2016. The aim of the study has been to answer the research questions *what, how, when and where* the single bicycle accidents occurred. The results showed that, about 2845 bicycle accidents occurred in Stockholm inner city, 48% was related to the category single bicycle and 31 % related to bicycle accidents between bicyclist and motor vehicle. The single bicycle accidents increased with 8% during 2010-2016. In terms of time, a correlation has been found between accident rate with bicycle flow as well time of season. The main causes appeared to be mostly due to poor operation maintenance, such as skidding due to snow, gravel and wet leaves, and also bicyclist interaction with road users where most accidents occurred when the bicyclist avoided with other road users. The majority of the victims had minor injuries 57%, only 3,5 % had severely injuries.

Even though Stockholm municipality has invested in several projects to promote bicycle flow and reduce bicycle accidents, critics are skeptical to these efforts, in terms of its adequately to meet the needs of a growing population as well as an increased bicycle flow in Stockholm. Although, several studies on bicycle accidents in Sweden have indicated that urban areas are the places were the occurrence of bicycle accidents is higher, an indication which has been supported by this study, as area prone to accidents were the urban area of Stockholm, in which the majority of the accidents occurred on bicycle path and road section. Based on the result of this study, preventing bicycle accidents seems to be the best way to go for achieving sustainability in transport. Thus, bicycling has shown having many advantages such as it emits less noise compared to motor vehicles, it is environmentally friendly, and bicycles, as a means of transport, give people exercise and contribute to achieving of sustainable development goals. Therefore, more resource should be used in finding the right tools to prevent bicycle accidents, especially single bicycle accidents, in order to increased bicycling.

The analysis of this study consists of compilation of bicycle accidents record that was extracted from STRADA (Swedish Traffic Accident Data Acquisition). The compilation was made with the help of Excel tool Pivotable and Analysis Tool Pak. The causes of single accidents were then classifying in the right categories by using Niska et al (2013a) five categorization on the causes of the single bicycle accidents: Operations and maintenance, road design, bicycle interaction, bicyclist's behavior and conditions, and interaction with other road users. The GIS software ArcMap was used to locate the areas prone to accidents. Due to the shortcoming in STRADA a semi-structural qualitative interview was conducted with bicyclists who bicycle in or along the investigated area. This study, which has been performed in collaboration with Stockholm traffic office, is relevant to the municipality, as it supplies new insight into bicyclists` experience of the physical environment.

Keywords: Bicycle accident, single-bicycle-accident, safety, sustainable development, Stockholm, STRADA

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Notations

Bicycle	Mean of transportation with two or more wheels, propelled only by humans' physical strength.
Bicyclist	A person who bicycle
Bicycle accident	An accident that occured on the road, and that involves at least on bicyclist.
Bicycle box	A colored area at a signalized intersection provided for bicyclists to pull in front of waiting traffic, with intention to diminish conflict between motor vehicle and bicycle when turning right.
Ethical Vetting	Swedish State Agency Etikprövningsnämnden, which has the purpose to protect integrity of an individual in research.
Informant	A bicyclist/person that contribute with data by participating in qualitative interview.
Investigate areas	The areas within Stockholm inner city that are investigated in this study.
Motor Vehicle	A self-propelled object whit wheel, such a car, truck to use on road.
Operation maintenance	Measures to maintain or restore a device such a road, to a state that it can fulfill its function.
Road	What is included in the term road according to the Swedish regulation Förordning om vägtrafikdefinitioner (2001:651) 2§: road, street, square, bicycle and pedestrians path as well riding path, (MSB, 2013).
Single bicycle accident	A bicycle accident involves only a bicyclist.
Stockholms Trafikkontoret	Swedish traffic agency, responsible for facilitating accessibility and safety for road users.
Transportstyrelsen	The Swedish transport agency with the purpose of authorizing, regulatory and transport supervision.
UN SDG	SDG stand for sustainable Development goals; a part of Agenda 2030 contains 17 universal goals with the aim to end poverty and protect the planet. These goals are created by United Nations.

Abbrevations

AIS	Abbreviated Injury Scale
ISS	Injury Severity Score
EMC	Emergency Medical Care
Strada	Swedish Traffic Accidents Data Acquisition.
VTI	Väg-och transport institutionen (Swedish national Road and Transport Research Institute)

1. Introduction

A bicycle is a useful tool from a health, environmental and climate change perspective so it is desirable that more people should bicycle (Björklund et al., 2017). Bicycling has many advantages: it emits less noise compared to motor vehicles, it is environmentally friendly, and bicycles, as a means of transport, give people exercise. The positive health effects that bicycling contributes to have been shown in Norway where Saelensminde (2002) has shown that for each bicycle trip, the Norwegian society saves five Norwegian Kroner which would have otherwise been spent on treating diseases, e.g. skeletal and diabetic diseases.

To encourage bicycling in Sweden, the Swedish government has promoted policies and proposals on national and local levels. The proposals Future travel and transport for sustainable growth expresses the government's willingness to work toward making Swedish society bicycle-friendly by building safe and secure bicycle networks (Näringsdepartementet, 2008).

At the same time, several pieces of research on bicycle use in Sweden show that more people are bicycling now than for 60 years ago. STRADA's (Swedish Traffic Accident Data Acquisition) reports also show that most people who are severely injured in traffic are bicyclists, and that most bicycle accidents occur in urban and metropolitan areas (Trafikverket et al, 2014a; Stockholm city, 2016: Niska et al 2013a). There is a need for more research on bicycle accidents in urban area.

Stockholm is a European city with a growing population. At the end of 2013 the population were 897 700 and it is predicted to grow by 25 % by 2030. This increase is estimated by the municipality of Stockholm to contribute to the demands of several construction projects including a well-functioning infrastructure that has the capacity to meet the needs of the population and an updated traffic system. The growing population offer an opportunity as well a challenge. About 10 % of the transportation during rush hour, in Stockholm, are made by bicycling and the municipality's goal is that by 2030, 15% of transportation during that time should consist of bicycling, to address population growth in a sustainable transport (Bandel et al., 2014; Firth, 2012).

Stockholm municipality is working on investment projects for bicycles with the aim of increasing accessibility and road safety, such as special road safety measures at intersections that often aim at improving conditions road for both pedestrians and bicyclists, and better maintenance of bicycle paths, both in summer and winter. Stockholm municipality invests a lot in winter maintenance, especially on the commuter lanes. One method used on commuter lanes during winter is that a machine brushing the snow and spreading a salt solution at the same time, instead of sand or gravel. In addition to this, the municipality has been involved in various campaigns for better interaction in traffic (Stockholm, 2018a). Critics and different debate articles about bicyclists` safety and accessibility, point out that the investments that Stockholm municipality is making are not enough for meeting the increasing population overall bicyclists in particular (Isaksson, 2012; Linde, 2015).

A report on how bicyclists experience the traffic situation in Stockholm and Copenhagen showed that bicyclists in Stockholm (1191 bicyclists) were more dissatisfied with how it is to bicycle in Stockholm. About 88% felt it was quick to get to the destination, but low proportions reporting that cooperation with other road users worked well (49%), safety was good (42%) and that the means of transport were priority (36%). For Copenhagen (1100 bicyclists), 75 % of bicyclists, which is lower than Stockholm, felt that it went quickly to get to one's destination, but for cooperation with other road users, safety, and good planning, Copenhagen shows a higher percentage of satisfaction, i.e. 61% for cooperation with other road users, 67% for safety and 71% for good planning (Koglin, 2013). Koglin's report show that there is still more to do for increasing bicycle safety and accessibility in Stockholm. Another report by Rietvel & Daniel (2004) and other research done on bicyclists' experiences of bicycling in urban areas indicated as well that there was a conflict between motorists and bicyclists on roads and that the perception of the risk of accidents affected the choice of the means of transport. Therefore, there is a need for more research on bicycle accidents in urban areas.

1.1. Bicycle safety in urban areas

Bicycling as a means of transport has many economically, environmentally and socially advantages (Saelensminde, 2002; Björklund et al., 2017). National and international research reports have shown that bicycle accidents have an impact beyond individual because of hospital costs, in the case costs of serious injuries, as well as fear of bicycling after the accident (Saelensminde, 2002). Research reports on bicycle accidents in Gothenburg indicate that those who have suffered from serious bicycle accidents stop bicycling because of the fear of injury, or that they were more careful when bicycling (Lundqvist, 2013). Based on the research of Lundqvist, I conclude that if bicycle accidents increase, more people may stop bicycling, which would counter the Swedish government's plan to make Swedish society bicycle-friendly, thus counteracting the possibility of sustainable transport. However, with better infrastructure accidents may or not occur less frequently.

Several research reports also show that separated bicycle paths have a higher number of injured bicyclists than shared paths (Lundqvist, 2013; Niska et al., 2013b). However, in Australia, it was shown that bicycle separation from pedestrians was safer than shared bicycle paths (Nixon et al., 1987). Pucher et al. (2013), on the other hand claim that separation of traffic is not a good solution if you want all road users to learn how to work together in shared public spaces. There are clearly different views on how to plan bicycle infrastructure in public spaces.

Copenhagen, one of the most bicycle-friendly cities in Europe, has prevented bicycle accidents by prioritizing bicycling infrastructure in the same way as motor vehicle infrastructure. Bicyclists have wide bicycle path, adequate space for passing, and decent bicycle paths at bus stops and at parking lots. It has been possible to encourage bicycling in society in Copenhagen (Högström, 2009). Therefore, the design of infrastructure is crucial if you want to stimulate bicycling in the city (Wärnhjelm, 2013). In a survey made by Niska et al. (2013b), it was found that spatial design and legislation are important for counteracting bicycle accidents. In their study of single bicycle accidents in Sweden, of 1,274 seriously injured bicyclists in single-accident cases between 2007–2011, 27 % were related to operation and maintenance, 20 % to road design, 27 % bicyclist interaction with the bicycle, 15 % bicyclist's behaviour and conditions, and 11 % for the interaction with other road users.

Since 2008, bicyclists in Sweden are the group of road users that are in hospitals the longest. According to the National Board of Health Patients' Register (SPAR), a third of road users hospitalized are bicyclists (Niska et al., 2013a). There are different types of bicycle accidents: bicycle- motor vehicle, bicycle-moped, bicycle-bicycle, bicycle-single, bicycle-pedestrian and bicycle-other. Bicycle single is the category with highest number of accidents in Sweden. According to Niska et al. (2013b) report on the amount of accidents between 2007-2011 and between different type of bicycle accidents, single bicycle accidents account for 71 % (see chapter 2, table 1) of the total bicycle accidents in Sweden and the causes are many. Niska et al has categorised different causes of these bicycle accidents and these are operation and maintenance, road design, bicyclist`s interaction with other bicycles, bicyclist behaviour and conditions, and bicyclist`s interaction with other road users. These categories are further explained in Appendix

1.2. Aim

The aim of this study is to analyse the cause of bicycle accidents in the city of Stockholm. Identifying causes of accidents can help decision makers and policy developers in the municipality of Stockholm to develop the right tools to improve bicycling. I do this by extracting traffic accident records from STRADA, thus identifying the location of bicycle accidents and the causes of bicycle accidents. STRADA as data has certain shortcomings (Howard & Linder, 2014), which is why a qualitative interview with bicyclists was added to increase credibility in the study.

1.3. Research questions

According to several research reports (Lundqvist, 2013; Niska et al., 2013b; Wärnhjelm, 2013), causes of bicycle accidents are a combination of several factors. These factors include the design of roads, place type, loose objects, weather conditions, and so on. Therefore, the research questions are:

1. When are bicyclists most likely to suffer an accident?
2. Why does an accident occur?
3. What causes are behind bicycle accidents at a chosen place of investigation?
4. Where are bicyclists most likely to suffer an accident?

1.4. Delimitation

This study has been delimited to include part of Stockholm inner city. The study areas that have been chosen for investigation include Södermalm, Norrmalm and Östermalm. I found that Stockholm inner city is large, and the concept of which part of Stockholm should include in inner city is subjective and has changed along with the expansion of Stockholm, therefore I have made my own concept of inner city (Map 1) that I choose to call *investigate areas.* Investigate areas includes Stockholm inner city and Stockholm city. The main reason that this part of Stockholm has been selected as the object of investigation is that previous research has mentioned the urban environment as a place where bicycle accidents occur more often. In addition, statistics show population growth in Stockholm while the reports of bicycling in Stockholm show that the number of bicyclists has increased as well (Trafikkontoret, 2018). Despite the city's investment in bicycle safety and accessibility, there are those that think this effort is not enough. The study is relevant to the municipality, as it supplies new insight into bicyclists` experience of the physical environment (Isaksson, 2012; Linde; 2015).

Further, the focus has been on STRADAs definition of single bicycle accidents that occurred during 2010-2016, and Niska et al`s. (2013b) categorization of causes of accidents were used. These categories are; operation and maintenance, road design, bicyclist`s interaction with other bicycle, bicyclist behaviour and conditions, and bicyclist`s interaction with other road users. These categories are further explained in Appendix 1. These delimitations have been necessary since the time allocated for this report is limited. In addition, the statistical data on single bicycle accidents used in this report are extracted from STRADA accidents report. Strada has been criticized as having shortcomings, as there are several severer and minor injury accidents that are not reported (Transportstyrelsen. 2018a). In 2015 statistic data for severely injured was missing totally because there were shortcomings in statistic reports from Emergency Medical care (Trafikanalys, 2016:12), therefore, qualitative interviews with bicyclists in Stockholm were done as a complement to this study. In addition, only accidents that occurred on the roads are used in this study.

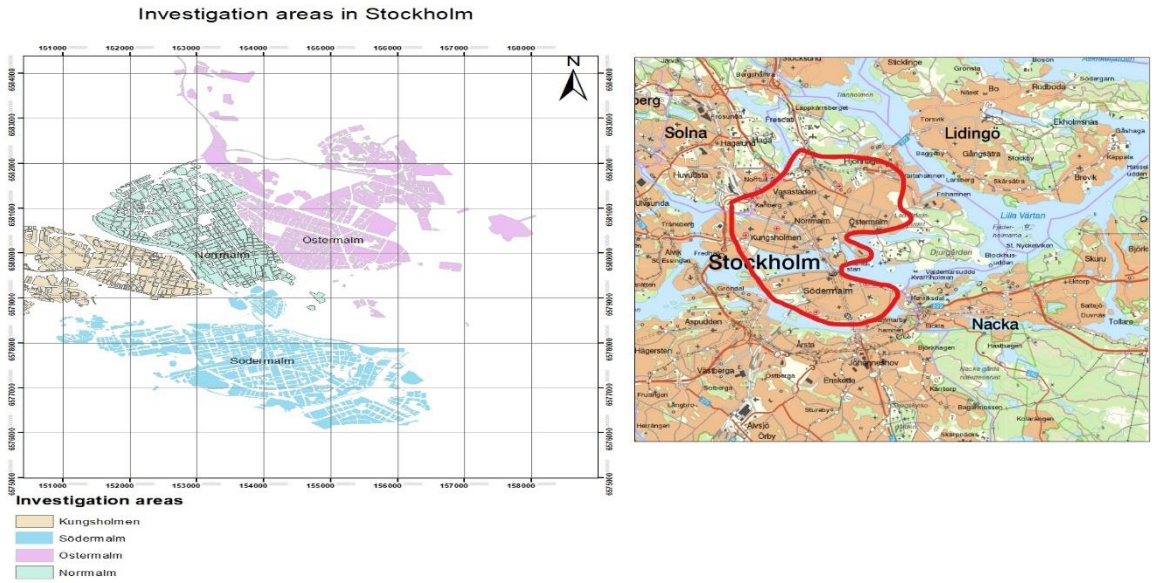

Figure. 1. This figure (left side) represents map over investigate areas boundaries. The areas are located in a part of Stockholm called inner city and Stockholm city, but in this study the areas are called investigate areas, and the map on the right side of investigated areas illustrates the area in which the investigate areas are located. The location I within the red line (Lantmäteriet, 2018; Stockholm stad, 2018).

1.5. Methods

The aim of this study was to analyse the causes of single bicycle accidents in the investigate areas in Stockholm inner city. The focus has been on STRADAs definition of single bicycle accidents that occurred during 2010-2016. A literature study was chosen as the preferred method to obtain a deeper background knowledge on bicycle accidents and their respective causes. The material includes scientific, peer reviewed articles, bachelor and PhD theses, as well as subject specific literature on bicycles. Most of the literature were obtained from Google Scholar, the library website of the Royal Institute of Technology, as well as Stockholm and Uppsala universities. The searching words used on internet included “where bicycle accidents in Sweden”, “bicycle accident”, “single bicycle accidents”, “the cause of bicycle accidents”, “how to prevent bicycle accidents” etc.

Furthermore, a course about how to use STRADA was obtained, with the Swedish Transport Agency, for getting access to bicycle accidents records in STRADA, a security and confidentiality agreement was signed before the course start. The course was 8 hours and obtained in Stockholm on 9/5/18 by. Thereafter the bicycle accidents records statistic was extracted in Excel and then manually examined to get an overview of data and remove the bicycle accidents that did not fit the aim of this report (Transportstyrelsen, 2018c).

Statistic data were then compiled in Excel using Excel tool PivotTable and Analysis Tool Pak to answer the questions: When are bicyclists most likely to suffer an accident, why does the accident occur, what causes are behind bicycle accidents at the chosen place of investigation? The cause of bicycle single accidents was many. By reading event descriptions about the cause of the accidents in Strada from healthcare and police, the cause of accidents was classified in the right categories by using Niska et al. (2013) five categorisation on the causes of the single bicycle accidents (See section 1.1).

In addition to categorization, the accidents were also distributed between years, months and hour of day. To facilitate the distribution of bicycling accidents between hour, a rounding of hour was made in Excel

Pivotable. There were several options to choose from, in Excel toolbox, namely rounding up or down. To round down means that if an accident occurred at 8.30 then it was rounded to 8 instead. In this survey, rounding downwards was chosen because if rounding up the accidents that occurred between 8-9 a.m. will change to 9-10 a.m. and would lower the credibility result more.

In the statistics data, there were also coordinates for each accident with information about where accidents occurred. The coordinates were then submitted into GIS ArcMap version 10.5.1., for further analysis about the place of accidents. To see which places where prone to accidents within the investigated area, a heatmap was created with GIS Software Arcmap tool called Density, 250 radiuses were used to get better visualisation of the accidents on the map and to include the accidents that might be far from each other. The results are presented in Chapter 4.

Furthermore, a semi-structural qualitative interview was conducted with bicyclists who bicycle in or along the report's field of investigation area. The purpose of the interview was to gather data about the bicyclists' experience of bicycling in Stockholm and to point out the areas that are risky to bicycle on, thus as a complement to STRADA´s data, to answer research question about the place that are prone to accidents as well the cause of accidents. The original idea was to interview bicyclists who had been involved in bicycle accidents, but the application to do so was not approved by Ethical Vetting.

Selection of interviewees was made by age (20-87). Around 25 bicyclists of different ages and gender were interviewed. Interviews were made by mobile phone and took around 20-45 minutes, the conversation was recorded for further processing. The questions were focused on:

- Bicycling habits
- Accessibility and Safety on the traffic road
- Operation maintenance
- Road design

The informants (bicyclists) were found through the Facebook group bicyclists in Stockholm, through companies that work with and use bicycle in their work (Cyklande Rörmokare, PostNord, Stockholm hemtjänst), and by volunteering for the Swedish association for bicyclists (Cykelfrämjandet) at the Kista fair event about bicycling. The interviews where recorded. Data processing was transcribed and coded. The main purpose was to find themes that could be connected to information gathered in STRADA accidents records. The questions to qualitative interview are found in Appendix 2

2. Theories and Literature studies on bicycle accidents in Sweden

2.1. Introduction

A literature study was chosen to gain background knowledge about bicycle accidents. The literature study contains historical background about bicycling in Sweden, the development of bicycle accidents in Sweden, measure to reduce bicycle accidents and bicycle flow in Stockholm. Then fallows a short presentation of policies about how to prevent bicycle accidents on national and local level. This is done to increase the understanding of bicycling in Sweden and the cause of the accidents, as well as to show how the municipality of Stockholm is working to reduce accidents. To get a view about how different individuals perceived the public space, the theory about room, time and the environment within the room is included to this chapter as well. The information will be used in the analyses and discussion the study's result.

2.2. Measuring stations and bicycle flow in Stockholm

Stockholm county has built a well-functioning bicycling roads and regional bicycle routes within the investigation areas, with the aim to link Stockholm's inner city and outer areas, and the purpose to relieve the public transport system on certain routes, the routes are designed in a way that facilitates the combination of public transport and bicycle when commuting (Stockholms, Läns landsting, 2016).

According to a travel survey made in Stockholm county made in 2015, residents in Stockholm region center have a smaller proportion of car journeys (27 %) comparing to residents in other parts of the county (58 %). Most trips are made with public transport (38 %), followed by car (27 %), walking (20 %) and bicycle (10%) (Stockholms läns landsting, 2016). Thus, there is a great potential for bicycle commuting to and from the inner city within 15 km radius. This is since 34 % of the workplaces are located in Stockholm inner city and 60 % of workplaces are in the region center including, the south and west of Stockholm, and almost half of the workforce are in these areas (Trafikverket et al., 2014b; Spolander, 2012).

Since 1980 Stockholm municipality has had measurement stations that measure bicycling flows in the city. Since 2011, the municipality has built fast stationary stations that calculate bicycling flow throughout the year. The measure stations are simply built with a beam that breaks when someone crosses the bicycle path or road to which they are targeted (Karlsson, 2000). In 2016, there were 55 bicycle stations distributed in Stockholm between 39 places and these station are installed at different times, 14 of them are in the investigated area. Stockholm municipality usually count the number of bicyclists that crosses the measurment stations at different place every year in spring (Maj/Jun) between 7-9 a.m, 12-14 p.m and 16-18 p.m (Stockholms trafikkontor, 2014) The results presented as a rolling five years value. Rolling five year are measuring by taking the value of each year under five years and then divided it by five. For example, for getting rolling five year value for 2016, the value of 2016 are measuring by adding the value of 2013-2016 and then divide it by five. This system is used to compose those days in years when the weather or other circumstances have created variations in the measurements (Stockholm, 2018b).

For this study, data with number of bicycling that have crossed through the investigate areas during 2010-2016 were retrieved in Excel form from the municipality website and then compiled in Excel. The rolling five-year values from measurement stations in the investigate area show that the number of bicyclists has increased with 4% during 2010-2016 (Fig. 2). But unfortunaterly the data contains only years values. Through contact with Per Karlsson at Trafikkontoret, I received login information to the measurements stations, and thus make withdrawals of bicycle flows in Excel form for the period 2012-2016 to get monthly value. The measurement stations are many in the investigate areas (14) and due to the limit of time I only chose two measurement sations (Munkbroleden and Strömsbron) that are located in the investigate areas (Fig. 3). These measurement stations were seleted as the streets have more traffic

than other places in the investigate areas. The time period (2012-2016) was selected because almost all data were missing for the years 2010 and 2011 due to the weather conditions. The measurement stations are sensitive to weather and do not always work well in the winter (Ibid).

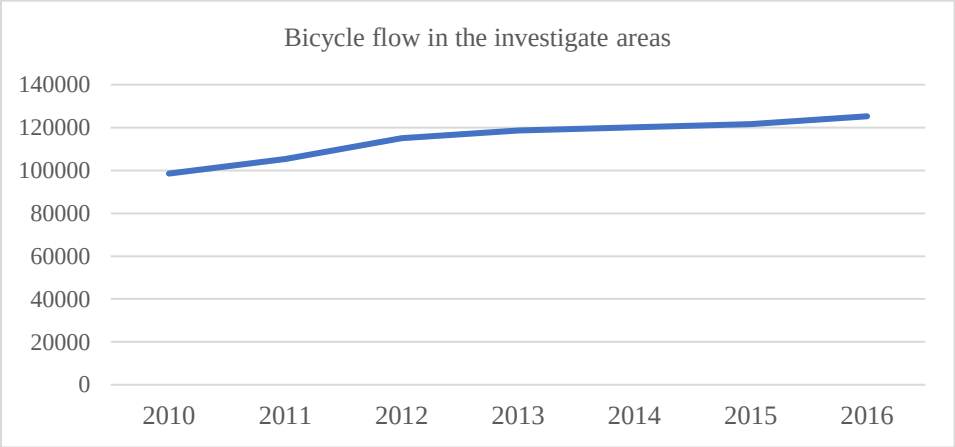

Figure 2: Number of bicycle flow in in the investigate areas based on 5 years rolling value, that Stockholm traffic office measured every year once at summer. The figure show that in 2010 the number of bicycle flow was 98540 and 125260 in 2016, an increasement of 4% during 2010-2016 (Stockholm, 2018a).

Figure. 3. This map is showing measuring stations in the investigated area. The blue points is the measuring station that measure bicycling flows at Munkbroleden in Gamla stan, and the black point is the measuring station at Strömbron. (Lantmäteriet, 2018; Stockholm, 2018).

Further, when I investigated the bicycle flow data manually there were a lot of data that was missing during winter time and also summer months for the period 2012-2016 as well. An estimation was made

to increase the credibility of the results. The missing values were replaced with the value generated by repetitions of the existing data, in order to avoid the problem of error sources. The method used is called multiple imputation. This method is considered to provide safer estimation because it contains the mean of all estimates made, compare if it had been used simple imputation where the missing value is replaced individually by a random value (Nyberg & Svensson, 2015). The results for Munkbroleden show that bicycle flows were almost constant with small increases between 2012-2014 and then higher during 2015, and lower in 2016. Unfortunaterly the station on Munbroleden had a long period of malfunctioning during 2014, 2015 and 2016. The data presented in Fig. 4 is manipulated with the multiple imputation method.

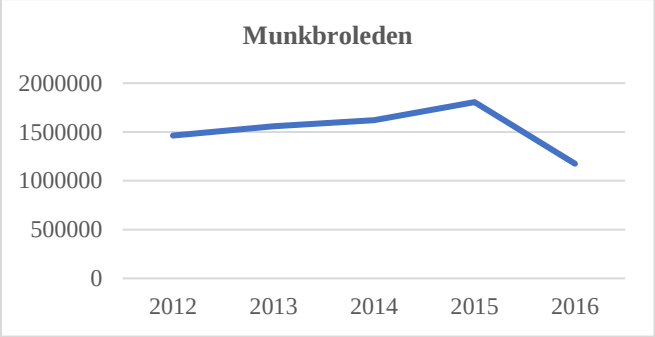

Figure. 4. The chart show how many bicycle has passed at Munkrobleden. Due to malfuction of the measuring stations, the data were misssing and were replaced with the value generated by repetitions of the existing data (Eco-visio, 2018).

For Strömsbron, the measure station had only 4 days where there were zero data collections. There were of course some days where the data was really scarce, especially during the winter period. However, the result shows an increase of bicycle flows during 2012 and 2016, with 5 %, for Strömsbron (Fig. 5).

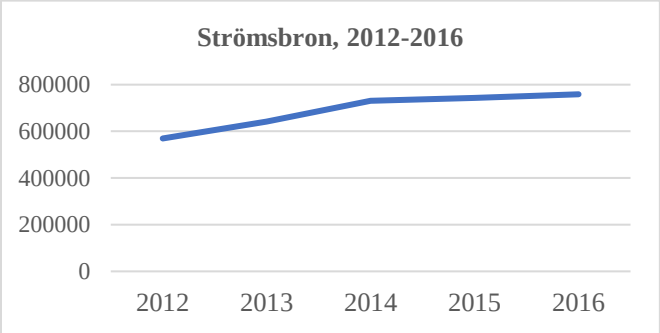

Figure. 5. The chart show how many bicycle has passed at Strömsbron measurestation, 2012-2016. Due to malfuction of the measuring stations, the data were misssing and were replaced with the value generated by repetitions of the existing data (Eco-visio 2017).

As mention before, the reason of withdrawal of bicycle flow at Munkbroleden and Strömsbron was to see the variation of bicycle flow during the month, therefore the number of bicyclists was further distributed between months of the years in Excel Pivot table. For Strömbron (Fig. 6), the month of August had the highest bicycle flows and least in January. On the other hand, Munkbroleden (Fig. 7) had highest bicycle flow in June and lowest during winter. The results indicate that the quantity of bicycle flow differ from different place. It is important to take into consideration that the data for Munkbronleden had several months of zero collected data which led to the use of multiple imputation, The bicycle mounth`s flow will be helpful when analysing single bicycle accidents the results (including

the result from rolling five years bicycle flow from Stockholm) in term of finding pattern/ relation between the accidents and bicycle flow.

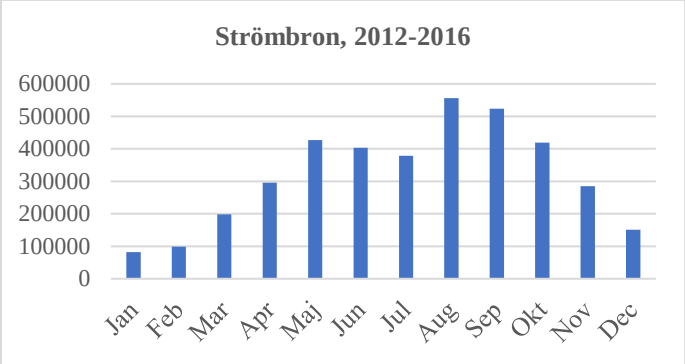

Figure. 6. The chart show how many bicycle has passed at Strömsbron during january and december (Eco-visio, 2017).

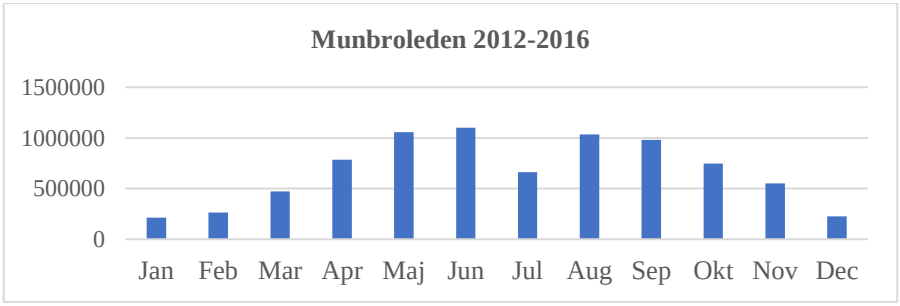

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Figure. 7. The chart show how many bicycle has passed at Munkrobleden (Eco-visi, 2017).

Further, weather data was extracted from SMHI for 2015 and 2016 (SMH, 2013) to see if bicycle flow fallow same pattern as the weather conditions, because previous reseach has shown the correlation between number of bicycle flow and weather condition (Karlsson, 2013). The data contains day time and month values. Month values were used for the chosen period and the result presented in Fig. 8 show that the air temperature follow the same pattern as the bicycle flows. In other word when its warm the bicycle flows are higher and when cold the bicycle flow is low. The weather data for 2016 shows a colder air temperature than the weather data for 2015. Unfortunaterly the weather data contains only data for two years while bicycle flow contains data for 4 years, therefore the pattern should be treated with cautious.

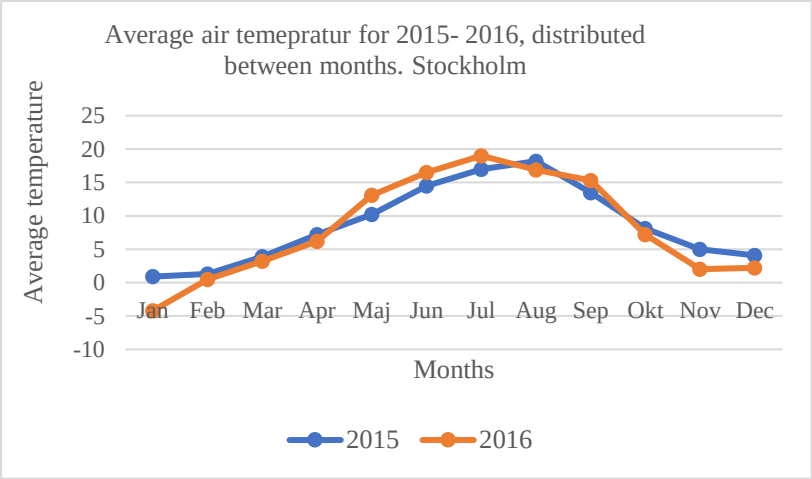

Figure. 8. The average temperature for each month for 2015 and 2016. Its more cold during winter period and warmer during summer for 2016 than 2015. Temperatur differ with 1,7-4 degree during winter and summer with 1-2 degree (SMHI, 2016).

2.3. Stockholm municipality and sustainable traffic

In order to prevent road accidents, bicycle accidents in particular, the Swedish government has created policies that are implemented on national and local level. Some of them included Zero Vision (Nollvisonen), Accomplishment Strategy (Framkomlighetsstrategi) and Bicycle Plan (Cykelplan), which are presented in this section.

The Swedish transport politic for road safety is based on the long-term national policy called Zero vision which mean no one should be killed or injured seriously in traffic, and that the transport system should be designed and adapted to this requirement (Prop 1996/97: 137). Zero vision has contributed to fatality having halved in Sweden over the last 20 years. As road accidents account for 20 % of all type of accidents, road safety has been included in the UN Global sustainability goal. The UN goals, which are part of agenda 2030, contains17 goals and are a call for action by all countries in the world to promote prosperity while protecting the planet (Trafikverket, 2017 & United Nations, 2018). Further, zero visions goal clarified in the policy Accomplishment Strategy(AS). AS is a part of the city of Stockholm's work to create a socially sustainable city. According to the AS, the population of Stockholm are increasing, and the number of people working and living in the city as well. The conditions change as Stockholm becomes more, and it in turn requires a changed approach to, and a changed view of, the city's travelers as well as traffic.

The accomplishment Strategy(Framkomlighetstrategi), which in comprehensive way, describes how politicians at municipal levels should prioritize different functions on the bicycle network. The strategy is divided into four parts:

- To make room for transportation that take less space per person (Bicycle Bus, walking)
- Increase free choices of transportation by making traffic more reliable
- Efficient and attractive systems of transportation in public spaces
- Reduce the negative aspects of traffic such as noise, personal injuries, emissions and barrier effects (Firth, 2012)

The Accomplishment Strategy(AS) state that 10 % of the transportation during rush hour, in Stockholm, are made by bicycling and the municipality’s goal is that by 2030, 15% of transportation during that time should consist of bicycling (Firth, 2012). Promoting bicycling in Stockholm is a way of reducing emissions in the transportation sector as this sector accounts for a third of all emissions in Sweden. This could contribute to reaching the UN’s Global Sustainable Development Goals.

AS is realized in the Stockholm Bicycle plan. Bicycle plan contains guidelines for how to promote bicycling in Stockholm, including how the design of the bicycle path should be designed based on the criteria of security, safety and effective mobility. The plan also stated thta (Stockholms stad, 2012; Trafikverket et al. 2014b). Promoting bicycling in Stockholm is a way of reducing emissions in the transportation sector as this sector is accounts for a third of all emissions in Sweden (Dickinson, 2018).

2.4. Bicycling in Sweden

Bicycling in Sweden has historically undergone different phases and stages, not only in terms of its physical design and use, but also the right to use it as a mean of transportation. During the 19th century, bicycles were reserved only for the richer middle class. With international competition on production, almost anyone could afford to have a bicycle, and this development led to a rise in bicycle density (Emanuel, 2012). However, the proportion of bicyclists decreased in the 50's to give place for the increase of motor vehicle and because of this shift, a construction of infrastructure in the public space was adapted to petrol powered motor vehicles rather than bicycles: Traffic planners came to prioritize motor vehicle traffic ahead of bicycles and pedestrian's safety in social planning. The consequences of traffic planning for motor vehicles, resulted in increased bicycle accidents (Ibid).

2.4.1. Bicycle accidents in Sweden

According to the official police report, reported by the MSB and VTI report, the number of bicycle accidents in Sweden has decreased by two thirds during 1987 to 2008 (Niska et al., 2010; MSB, 2013a). The police report could also show that the bicycle fatalities have decreased from 171 to 28 persons per year in general, but for 2015 the number of fatalities was 17 for bicyclists, which represented 6% of the total fatalities of all road traffic, where motor vehicle was over represented with 56 %, followed by 17 % for MC and 11% pedestrians. The fatalities number 17 for bicyclists was the lowest fatality number in this traffic category, since the statistics began in Sweden. The age of the victims for 2015 statistic were 19 up and the majority were men (Trafikanalys, 2016).

According to Niska et al. (2013a), the credibility of quality of official police statistics report on fatalities in terms of road accidents is high, but low on statistics on bicycle accidents contains victims with severe to minor injuries, especially in the category single bicycle accidents which many other researchers have concluded (Trafikanalys, 2016). However, the cause of the shortcomings in police official statistic reports on severe and minor injured bicyclists are caused by several factors. One of them is the lack of time as the police at times cannot be present when accidents occur. Other reasons may be that the victims choose not to report the accidents due to different reasons, and sometimes the hospital has shortcomings too, in reporting. The report for 2015 was inadequate because of the problem with hospital reporting to STRADA, which resulted in missing data for injured persons in 2015 (Berg, 2018).

In addition to statistics from the police, Trafikanalys (2016), has also reported statistics from patient records about the number of people treated in more than 24 hospitals where a moving vehicle has been involved. In the latest report covering the period 1984-2014, it appeared that the number of traffic injuries has fallen by 25% to today´s 8000 victims (2014) in Sweden. But since 2008, bicyclists have surpassed motorists in terms of the number of injured victims needing medical care. Trafikanalys (2016) concluded in their report that the reason decreased traffic injuries in Sweden might be due to new reforms by Swedish government from 1923 until now, that aimed to increase traffic safety (even though most of them were mainly reforms for motorists). Moreover, some of the reforms included changing traffic from left to right, use of helmets, and limiting the allowed amount of alcohol consumed while driving.

In addition to Trafikanalys´ conclusion, several pieces of research could conclude that use of helmets in general could ease the level of injury in terms of accidents; a survey made in Sweden about how bicycle accidents caused injury lead to long sick leave, found that the victims with head injuries had longer sick leave than other type of injuries. Another survey made in the US on the effectiveness of helmets in case of bicycle accidents concluded that the helmet was 85% effective to prevent head injuries. The survey contains a case group with people injured in bicycle accidents and different control groups. In the group

with the highest head injuries (case group), only 4 % of 99 injured persons had helmets and for the control group without head injurie, 24 % had helmet at the time of accidents (Thompson et al, 1989).

Based on Trafikanalys` reports (2016), a conclusion can be drawn that bicycle accidents have decreased both in terms of the number of deaths and the number of serious injured victims in Sweden during 1987-2011. At the same time, it is pointed out that there are several severe and minor injury accidents that are not reported. The Swedish Traffic agency (Transportstyrelsen, 2018a) advices to take into consideration underreporting when concluding that the bicycle accidents have decreased or increased in Sweden.

2.4.2. The cause of bicycle accidents in Sweden

Niska et al (2013b) made a survey based on bicycle single accident in Sweden during 2007-2011, where they studied bicyclists who were seriously injured (ISS9-). The survey included 1274 severely injured bicyclists reported in the Strada hospital report. The results presented on table 1 show that most of the accidents were single accidents (71%). The table also shows that it was only 1% each of the total accidents that involved accidents between bicyclists and pedestrians, and between bicycle moped. Accidents between motor vehicle and bicyclists were also less (18 %) than single bicycle accidents in Sweden.

Table 1. Bicycle accidents divided between type of accidents (Niska et al., 2013a).

Bicycle single	71%
Bicycle- vehicle	18%
Bicycle pedestrian	1 %
Bicycle- bicycle	6%
Bicycle- moped	1%
Other	3%

Further, the results of another report from Niska et al (2013a) and other researchers show a correlation between the amount of bicycle accidents and the time of occurrence. During the summer (May-September), the bicyclist flows were higher than in the winter in many of Swedish urban area, (Stockholm trafikkontor, 2017; Karlsson, 2000).

The survey made in Gävle about the correlation between bicycle flow and weather observations could show that the weather conditions as well affected the number of bicyclists. In terms of temperature, the percentage of bicyclists decreased by approximately 19.3% when the temperature ranged between minus one and plus one degrees compared to if the temperature was in the range between plus five to plus ten degrees. For lower temperatures in the range of minus ten to minus five degrees, the proportion of bicyclists decreased by 28.7% relative to the number of bicyclists in the range between plus five to plus ten degrees (Karlsson, 2000). Seasons of weather impacts on bicycle accidents, both the number and bicycles can depend on different factors, one of the factors, in my view may be that bicyclists are unprotected road users and because of this, many bicyclists refrain from bicycling in bad weather condition while in fine weather there are several bicycles.

Time of the day, between 7-8 a.m. and 16-17 a.m. had also higher bicycle accidents in Niska et al´s. (2013a & 2013b) report. Another report about Stockholm's county populations traffic habits showed that number of travelers were higher between 7-9 a.m. and 16-18 p.m. and most of the travel are to and from work. The report was a survey made on a sample of 129000 people in the age 16-84 (Stockholm's läns landsting, 2016). The reports indicate that some hours during the day are more prone to accidents than others. These reports indicate that there may be a correlation between number of travelers and the accidents.

In order to facilitate analysis of the cause of bicycle accidents Niska et al. (2013b) have categorized different main categories that cause bicycle accidents; operations maintenance, road design, state and behaviour of the bicyclist, bicyclist interaction with bicycle, and bicyclist interaction with another road user. The result of their survey made during 2007-2011 could indicate that almost half of the bicycle

accidents were due to operation and maintenance, followed by road design and bicyclist behaviour and conditions (table 2). Skidding created by ice, gravel, leaves or other objects on roads are those listed as the main cause of serious injury to operations and maintenance. The accident caused in category road design were mostly due to driving against curb stone, and bicyclists behavior and conditions as speaking on the phone while bicycling (Niska et al., 2013b). For further information, see Appendix 1, where there is all information about what can cause bicycle accidents in each main category, based on Niska et al. (2013b) categorization.

Table. 2. The main cause of bicycle accident in Sweden based on hospital report on severe injured (Niska el at., 2013a).

Categories:	Percent
Operations Maintenance	27 %
Road design	20 %
State and Behaviour	15 %
Bicyclist interaction with bicycle	27 %
Bicyclist interaction with another road user	11 %

2.5. Measures to reduce accidents

The design of the infrastructure is important if you want to combat traffic accidents. According to Niska et al´s. (2013b) survey, spatial design and legislation are important for counteracting bicycle accidents. Much research pointed out that the state of the physical environment and road design are of major importance to road safety for bicyclists (Niska et al., 2013b; Nixon et al., 1987; Wärnhjelm, 2013). Improvement of the road design for bicyclists through various measures such as speed limitation, separated bicycle paths, has shown a positive impact on road safety for bicyclists. A survey in the Netherlands showed that a separated bicycle path combined with lower speed, contributed to reducing bicycle accidents (Niska et al., 2013a).

In addition, the width of bicycle path is also important in the case of accidents. Widening bicycle paths, especially at double directional bicycle path, can have good traffic safety effects; a wide bicycle facilitates passing and prevent crashes. Svenska Dagbladet, a major Swedish newspaper, writes in an article that the number of injured people due to collisions between bicyclists and pedestrians in Sweden has increased in recent years, especially in the spring, the explanation to this is that bicyclists has increased in number in urban areas and infrastructure and road design have not adapted to this (Blume, 2013). Even though, research conclude that the greater the number of bicyclists, the more the bicyclists are visible to other road users and the more safety increases (Schepers, 2017). However, a larger number of bicyclists on a narrow bicycle path gives the opposite effect as crowded bicycle paths increase the risk of bicycle accidents.

Some traffic safety measures have given the opposite effect. Curb stones whose purpose is to separate pedestrians and driving lanes has been one of the main causes of serious road accidents (Niska et al., 2013a). These can be removed or lowered if possible. Orientation through road signs is good, as studies have shown connection between longer journeys in new environments and increased bicycling accidents (Niska et al., 2016). When bicycling in a new environment, one cannot be aware to the dangers of the roads.

Further, facilitating accessibility for bicyclists while increasing safety is a prerequisite that benefits society in the long term, economically, environmentally and socially, as reduced accidents also reduce

hospital costs while more people dare to bicycle and contribute to a better environment (Niska et al., 2013a).

2.6. Theory about how individuals experience the room, time and place

A way to respond to the population growth in Stockholm is to plan the public space effectively, as a growing population will demand more space (Firth, 2012). In my view, a good planning requires knowledge about those to whom the planning is made for, in this case the road users. Understanding of the function of the room could be helpful when analyzing the cause of single bicycle accidents. This might be an increased knowledge about how the shape of the public space can affect different individuals during different time in a society.

Arafi (1999) suggest, in his theory of the experience of the room, time and place, that individuals experience of the room should be taking into consideration when planning the room, because their experience, according to him, is subjective and are shaped by various factors as cultural value, gender, age, economic preferences, experience and professional backgrounds etc. He further argues that sense of safety increases the more the individual feel proximity. What Arafi tries to say with the theory is that planners should strive to plan a room that corresponds to the needs of the individuals and when the individual feels the sense of connection with the room, the sense of proximity to the room will rise as well as the feeling of safety. He further argues that it is important for individuals' opportunities of maintaining their daily lives. Lack of accessibility, time as well as transportation possibilities could constrain individual capacity for action and increase stress and speed. In today's society there is usually a wide range of transport and communication resources available, which makes it relatively easy for people to move in space. Sometimes it is not the absolute distance in meters or kilometers that becomes the most important when an individual move to a place from another. With the availability of different transports, it creates a cognitive distance, that is, how different individuals themselves perceive the distance to different places. The perception is based on one's own experiences, stories, pictures, or in a combination of several of the aspects. A distance in space or travel time is easy to measure. However, the cognitive perceived distance is more difficult to measure because it is individual. In the perceived distance, factors such as e.g. travel costs or effort for the travels are included (Cottman, 2014:16).

3. STRADA

The purpose with a background description of Strada and how Strada has been used in this report in this chapter, is to facilitate the reader's understanding of the analysis of the cause of bicycle accidents in the chosen investigate area in Stockholm inner city. The first part of the chapter contains a brief description of the Strada, then an additional description with focus on those who report to Strada (police and Emergency Medical Care) and the chapter concludes with a description of how Strada has used in this study.

3.1. Introduction to STRADA

STRADA (Swedish Traffic Accident Data Acquisition) is a Swedish GIS (Geographic Information system) model that contains data on road transport accidents and injuries, which have taken place throughout the country of Sweden (Howard & Linder, 2014). Strada accident report contains information about what, how, when and where the road accidents occurred.

The purpose of Strada is to facilitate road safety work and to gather statistics and researches. Those who use Strada in road safety work include road owners, municipalities, as well as researchers and insurance companies (Howard & Linder, 2014; Näringsdepartementet, 2016). For example, insurance companies can use data to prevent accidents and reduce their expenses, or a municipality can work with data for road safety purposes; for example, a road sections with a lot of reported single accidents can provide information about where the police should be at a speed control. Strada facilitates the traffic safety work by providing information that helps the municipality to put the right resources in the right place and at the right time (Näringsdepartementet, 2016). According to Berg[1], data is pseudonymized, which means that it is not possible for data user to link information to the accident victim in Strada, not even the Swedish transport agency(Transportstyrelsen) can identify who is behind the ID number (Berg, 2018). To obtain information about the person, you must apply for permission to Ethical Vetting (EPN, 2018).

The report in STRADA comes from two sources: the police and Emergency Medical Care (EMC). EMC are not obliging to report road accidents to Strada, like the police, and because of this, different EMC have joined Strada different times, and 2016 were all EMC in Stockholm County connected to Strada (see Appendix 3). The EMC within investigate areas are Södersjukhuset. City Akuten Närakuten and Capio S:t Göran and these near the areas are Astrid Lindgrens barnsjukhus and Karolinska universitet sjukhus Solna (Fig. 9) (Transportstyrelsen, 2018b). Further, Berg said[2] during Strada cource that, unlike police, the EMC receives a small fee from Swedish Transport agency for their connection to STRADA

An important difference between the police and hospital report is that the police provides one accident report per accident and hospital one accident report per person (Howard & Linder, 2014).

3.2. How the Police reports in Strada

Report in Strada from the Police became mandatory in 2003 and the police are obliged to report all accidents throughout the road transport system (Berg, 2018). The information in the police report is divided in three categories: accident, traffic element and person. Accident contains all accidents circumstances: weather, place, time road conditions, location and type of accidents. Traffic element is the motor vehicle (or bicycle, pedestrians) that are involve in the accident and *Person* has information (social security number, gender, age) about the person/element that are involved in accident (Howard & Linder, 2014). Additionally, the police provide an event description of the cause of the accident. The information is written down on a form and then to be reported to STRADA database. Due to the limitations in medical assessment, the police cannot determine a victim's injuries the same way as hospitals do. Therefore, the police use three categories, i.e. severe injuries(ISS9-), moderate injuries (ISS 4-9) and minor injuries (ISS 1-3), these will be used in this study when categorizing the injuries of

[1] Berg, Transportstyrelsen, 2018-05-09
[2] Berg, Transportstyrelsen, 2018- 05-09

the victim of single bicycle accidents in the investigated areas. Moreover, the police can also maintain the information about an accident through the victim calling the police and report the accident (Howard & Linder, 2014).

3.4. How the Emergency Medical Care reports in Strada

Unlike how the police reports, the emergency medical care (EMC) report consists of a deeper and more detailed description of injuries that occurred during an accident. Emergency medical care has several different journals to send to Strada: traffic accident record, supplementary journal, x-ray journal, and ambulance journal (Howard & Linder, 2014). EMC provide the patient with a form to be filled in with information about accident, location, roadmap, positioning, time and cause. If the patient came to a hospital with an ambulance, the ambulance staff may have already filled in these data in ambulance journal. Thereafter EMC records down injuries and the time the person is hospitalized. In addition, EMC also provides information about injuries that has occurred / has not occurred in another journal. EMC uses injury Abbreviated Injury Scale (AIS) and ISS (Injury Severity Score) to describe the degree of injury reported in Strada. AIS measure severity of all injuries on the body on scale from one to six. The AIS code indicates where the body is injured, what extent is the injury and how serious the injuries are. ISS is a summary of AIS and indicates by EMC to categorize the risk of the person's ability to survive his injuries. Minor Injury (ISS 1–3) mean least threat to life, and severity Injury (ISS 9-) more threat to life (Berg 2018; Howard & Linder, 2014).

3.4. Matching police and EMC

The matches between the police and EMC report is governed by the accident victim's social security number, time and position where the accident occurred, counted plus minus 24 h. Thirty percent of reported accidents belong to the match. A person`s social security number is the criterion that has the greatest importance for the match. For example, social security number and time the accident occurred can result in a match even though the positions are more than 1000 meters apart. Matching can also be done without a social security number, for example between two medical reports. The Q value (1-100) used to indicates the strength of the reports that have been matched; a Q value of at least 65 is required for the match to be accepted (Berg, 2018; Howard & Linder, 2014).

3.5. Work procedure in Strada

In order to answer the research questions what, when, how and where single bicycle accidents occurred, bicycle accidents that occurred between 2010-2016, in the investigated area, were selected in Strada database. After the selection was completed, the result was displayed on the map. To visualize on the map in Strada which source (polis and EMC) was the basis of the report, different letters are used: P for polis, S for EMC and SP for the report that match both (Table.3) (Howard & Linder, 2014). The data was then imported in Excel file for further processing and analysis. The Excel file contained windows with: *Summary of bicycle accidents from police and EMC, Accidents, Person, Person police, Person hospitals, Injuries and Serious injuries.* In this study, windows with People accident report consist of number of victim per accidents where used, because it contained accident reports from both police and hospitals, and age and gender of the accidents victim which was missing in the other windows. Age and gender are important complements to include in the report as it can provide information on how bicycle accidents that are important for the design of bicycle infrastructure.

Bicycle accidents reported in the window *People* were categorized based on different types of bicycle accidents (Table. 4). Accidents that had the same type were classified in the appropriate categories. This facilitated the compilation of accidents, which was practical because the intent with this study was to analyzing bicycle single bicycle accidents and not all the type of accidents. Further information on how the compilation and analysis was made is to be found in the Method section, and results of the compilation can be found in Chapter 4, Part 1.

Table 3. Different colours used in Strada to distinguish the source where the bicycle accidents report come from. accidents in Strada (Berg & Andersson, 2018).

P	Police
H	hospitals
P/H	Police/Hospitals

Table 4. Accident type category provided in Strada. Category VO contains bicycle accidents from all category. (Transportstyrelsen, 2018).

GI	Bicycle single
G3	Bicycle - pedestrian
G4	Bicycle- bicycle
G5	Bicycle-Moped
C	Bicycle/moped-Motor vehicle
VO	Other
W	Wild animal

Figure. 9. The location where the Emergency medical hospitals are located in the investigate areas, in Stockholm. (Lantmäteriet. 2018).

4. Empirical analysis

4.1Introduction

This chapter has been devoted solely to empirical analysis. The empirical analysis of the report is divided in two parts: First part contains bicycle accidents from STRADA, with a focus on single bicycle accidents that occurred during 2010-2016 in the chosen investigate area (See section 1:4). The second part contains qualitative interviews with bicyclists in Stockholm and inventory of the places which the interview pointed out as risky to bicycle at. Before a deep study of single bicycle accidents, a brief overview of bicycle accidents in general, distributed between time, place and gender as well as between different categories are presented at the beginning of part. First a heatmap contain bicycle accidents in Stockholm is presented.

4.2. Area prone to bicycle accidents

During 2010- 2016, 2844 bicycle accidents were reported in Strada, in the investigate area, of these 1365 were single bicycle accidents and only 1277 had event description. However, to visualize were the intensity of the bicycle accidents within the investigate area a heatmap was produced, using GIS tools Point Density with 250 radiuses. The measurement, 250 radiuses was used due to the shortcoming and uncertainty about the location of the accidents. The accidents included also all accidents occurred in Stockholm during the same period. This was made to compare the intensity of accidents in investigated areas in relation to bicycle accidents in the investigated areas. The heat map shows that the areas with highest accidents in Stockholm are in the investigate areas (Fig. 10). When examine the heatmap, the red colour indicates places with highest density of accidents, yellow colour indicates places with second highest density and colour green lowest density. In conclusion, the heat map indicates that area prone to bicycle accidents in Stockholm are within the investigated area and this results of heatmap confirms Niska et al. (2013b) indication that most bicycle accidents occurred in urban area.

Figure. 10. This heatmap show areas prone to bicycle accidents in Stockholm municipality. The map represents the bicycle accidents that occurred during 2010-2016. The places with red colour are those with highest density of accidents and the green are places with lowest density (Lantmäteriet, 2018).

Of these 1277 single bicycle accidents, only 172 were reported by the police and 213 had uncertain positions. Before a deep study of single bicycle accidents, a brief overview of bicycle accidents in general, distributed between time, place and gender as well as between different categories is presented at the beginning of part 1.

4.3. Bicycle accidents in general

The heat map shows that most bicycle accidents are in the investigate area. The bicycle accidents increased with 158 bicycle accidents between 2010-2016 (Fig. 11) which corresponds to 5 %.

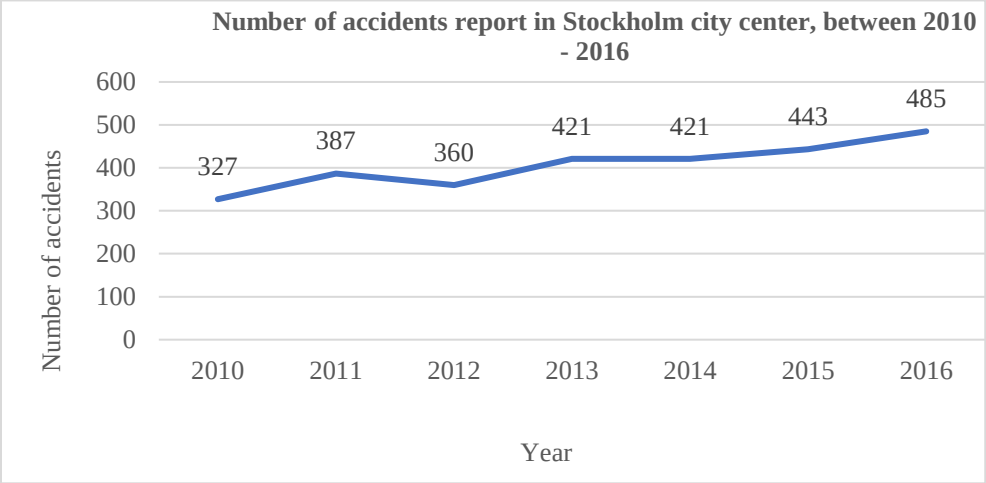

Figure. 11. Numbers of bicycle accidents in Stockholm between 2010- 2016 in the investigate areas. The results show that the number of accidents vary every year. In 2010 it was reported 387 accidents and 2016 485 accidents.

In terms of gender, men were overrepresented in the number of accidents. This group had 54% of the total number of bicycle accidents in the investigate area, compared to women's 37% (Table. 5), but according to Stockholm traffic agency (Trafikkontoret), men bicycle more than women (Stockholms Trafikkontoret, 2018) in Stockholm which can be the reason to why they are overrepresented in bicycle accidents.

Table. 5. The number of bicycle accidents distributed between gender.

Gender	Percent
Man	54 %
Women	37 %
Unknown	9 %

Further the number of accidents was distributed between months. The results of the compilation indicate that the accidents during the winter time (November- February) was quite low compared with the other season of years (Spring, Summer, fall). The months with higher accidents was June and August, and with the lowest are January and February (Fig. 12).

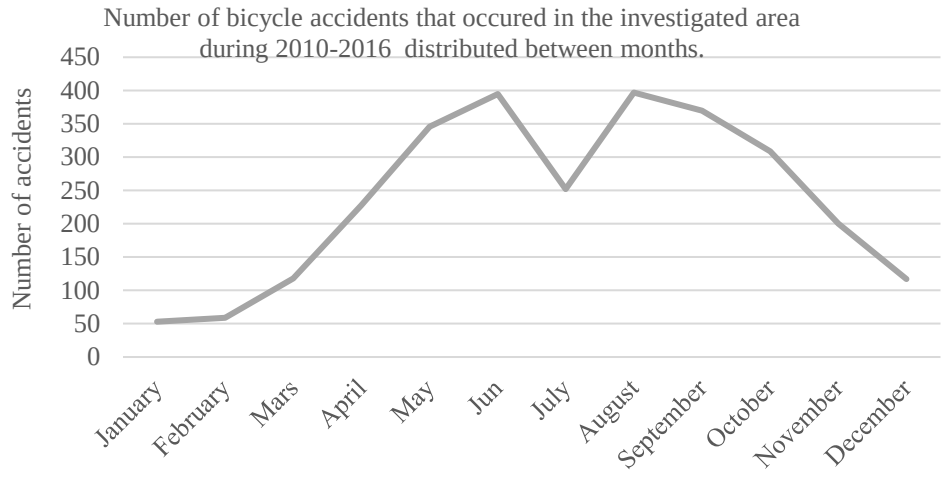

Figure. 12. The distribution of bicycle accidents between months in 2010 to 2016. The results show that the number of accidents varies considerably between the four seasons, especially between summer and winter.

The victim of bicycle accidents had different grade of injuries. Most accidents in the investigated area had minor injurie grade (63%). Only 3 % had ISS 9 and less than 1% was fatal accidents. ISS is a summary of all injuries on the body and indicates by Emergency Medical Care (EMC) to categorize the risk of the person's ability to survive his injuries (Howard & Linder, 2014).

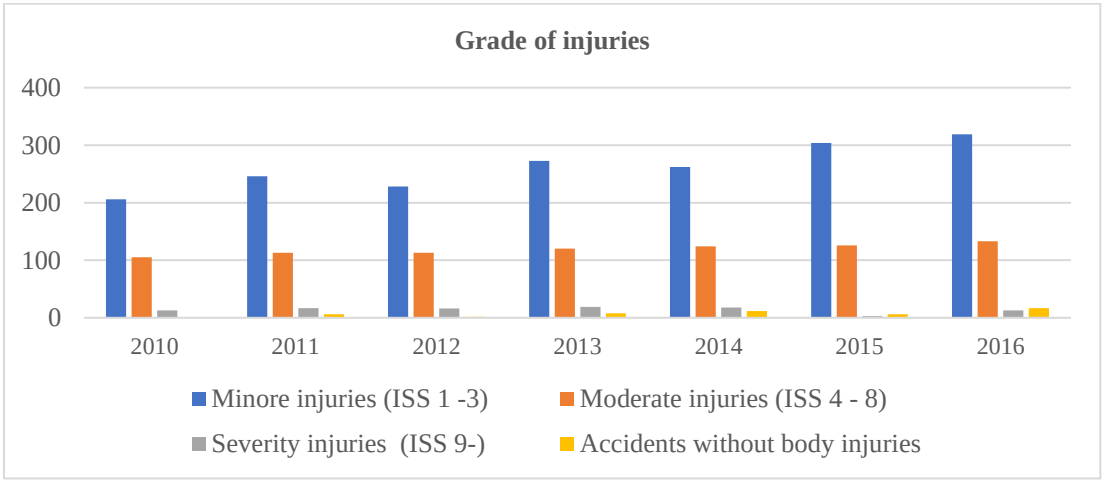

Figure. 13. Number of bicycle accidents distributed between grade of injuries.

To get an overview over the place type that is prone to bicycle accidents, accidents were distributed between type of place according to Strada classification of type of place where accidents occurred (See section 1.5). The compilation indicated that the occurrence of bicycle accidents differed between type of place and between years: During 2010-2013 and 2015, most bicycle accidents occurred on road section, but for 2014 and 2016, most bicycle accidents were on bicycle path (Fig. 14).

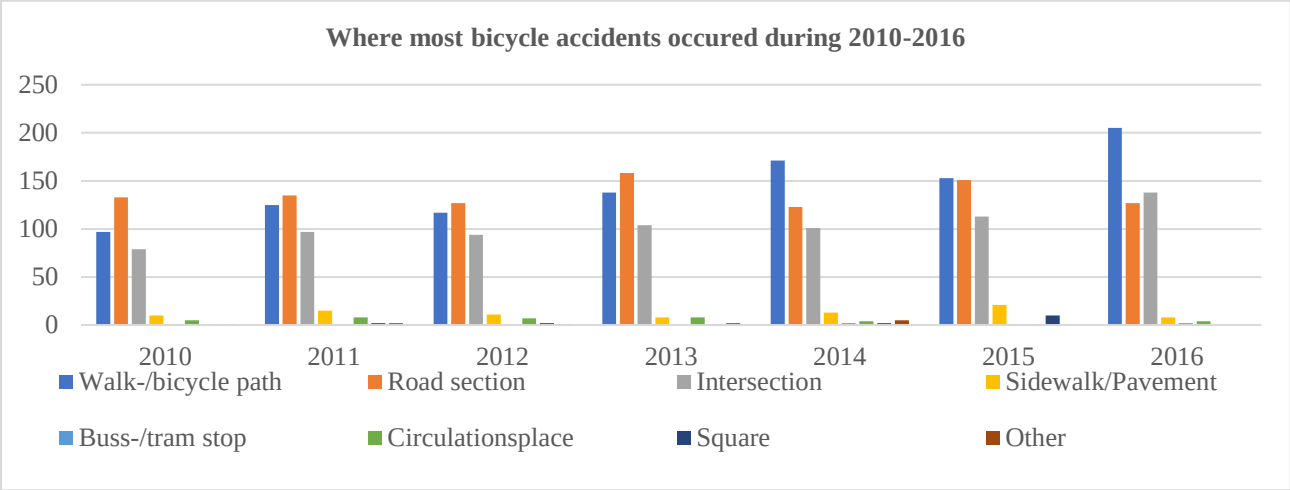

Figure. 14. The place type where bicycle accidents occurred most.

In the case of the type of bicycle accidents, its appear that single bicycle accidents were more frequently than the other bicycle accidents type, with 48 % of the total bicycle accidents in the investigated area. When compare with bicycle accidents type in Sweden that occurred during 2007-2011, the single bicycle accidents were more frequently as well but the percentage was higher (71%). On the other hand the bicycle accidents between bicycle and car/ was only 18 % in Sweden (Niska et al., 2013b) compare to 31 % in the investigate area (Fig. 15). The difference may be since the investigated areas for this study are in urban environment with high traffic, therefore 31% of the accidents are related to accident type bicycle -car/truck.

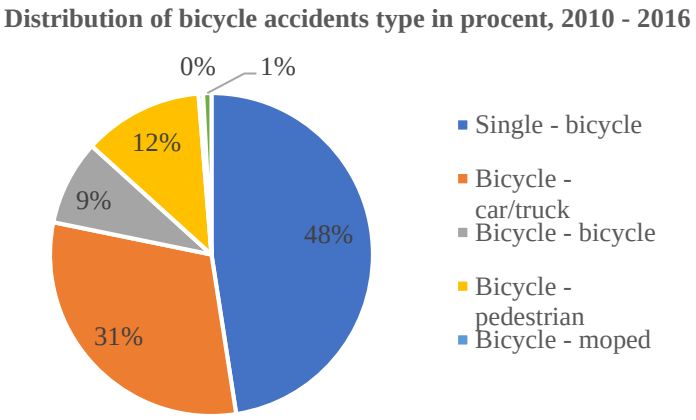

Figure. 15. Bicycle accidents occurred in the investigated areas during 2010-2016, distributed between different type of bicycle accidents.

4.4. Single bicycle accidents

The section 4.3 was focused on analysis of all type of bicycle accidents based on place time and gender in the investigate areas. In this section single bicycle accidents are presented with the focuses on trying to answer the main objective of this study, which is analysis of single bicycle accidents occurred in the chosen investigate areas in Stockholm. The analysis is based on the accidents report extracted from STRADA accidents records. The number of single bicycle accidents during 2010-2016 were 1368 and represents 48 % of all type of bicycle accidents occurred in the same period, at the investigate area (Fig.15). When investigating the single bicycle accidents manually its appears that only 1277 had an event description, 217 had uncertain location but street name, 67 accidents with unknown cause and 64 with uncertain time of the day.

Furthermore, single bicycle accidents were compiled in Excel tool Pivot table to answer the report research questions: When are bicyclists most likely to suffer an accident, why does the accident occur, what causes are behind bicycle accidents at the chosen place of investigation, where are bicyclist's most likely to suffer accidents. To answer those questions the causes, time and place of accidents were analysed. As mention before on method in section 1.5, Strada accidents record have an event description about the accidents. This event was used also to categorize the causes of bicycle accidents.

The cause of the single bicycle accidents was many, and it was difficult to categorize because an accident could have several causes that affect each other, but Niska et al. (2013b) have facilitated categorisation trough different indications that indicate which single accidents fits in which category (Appendix 1). The accident causes were divided into 5 main categories: operation and maintenance, road design, bicyclist's interaction with bicycle, bicyclist behaviour and bicyclist's interaction with other road users but only 5 of them were used in this study. The results of the main causes of bicycle accidents are presented below (Fig. 16).

Each 5-main category were analysed to further categorize subcategories of causes. Subcategories are the information written in the event description that the injured bicyclist gives as the reason that the accidents occurred.

Further, the hour when the accidents occurred, in each category, was rounded with the help of Excel toolbox; if an accident occurred at 8:15, the time was rounded down to 8. This was made to get a clearer chart over time. All results of the causes of single bicycle accidents and where the accidents occurred are presented below.

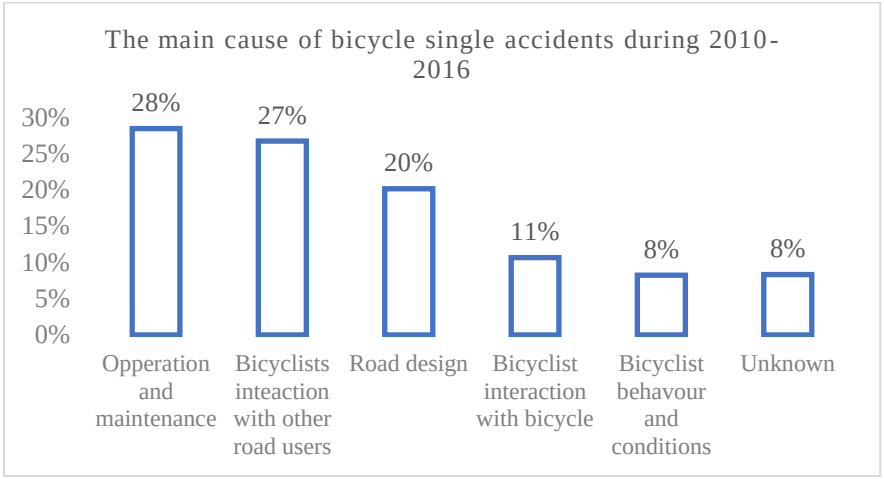

Figure. 16. The bar chart illustrates the cause of bicycle accidents for the investigate area in Stockholm. The accidents are distributed based on VTI categorisation of what cause single bicycle accident.

4.4.1. Operation and maintenance

Single bicycle accidents related to operation maintenance stood for 28 % of the total number of accidents that occurred in the investigated area during 2010-2016 (Fig. 16), compare with 27% for the whole country, in the same main category (Niska et al., 2013b)**.** According to the chart (Fig. 17), accidents in this main category has increased with 12 % during 2010-2016. The accidents show a rising trend except in 2015 when accidents were a bit lower and broke the rising trend. This could be because 2015 had a milder winter than 2016 (SMHI, 2013) and this could had contributed to less gravel used during the winter to prevent slip and this in turn contributes to less accidents during the spring caused by slippery from gravel.

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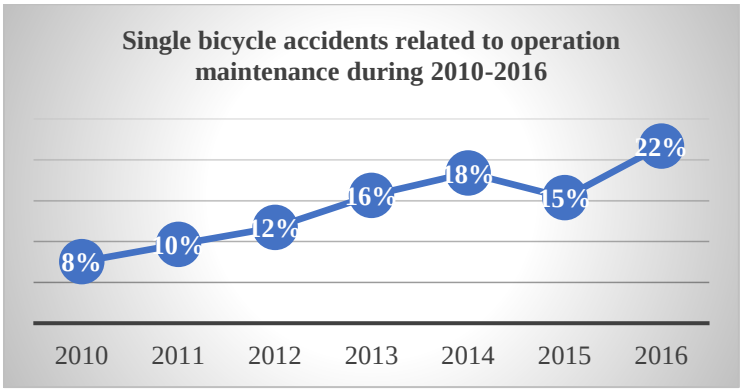

Figure. 17. The chart single bicycle accidents as percentage. The blue line shows how the amount of percent accidents occurred each year, in Stockholm city.

Furthermore, skidding seems to be the cause of the accidents in this category: the greater proportion of accidents related to operation and maintenance were unknown skidding where the victims said they slipped on something but could not know what is was. Other were slippery due to ice, leave and gravel. Other external factors that enhance the emergence of the accident could be darkness, down and uphill in combination with suspended snow or wet leaves or other loose objects such as glass pieces etc (Figure 18).

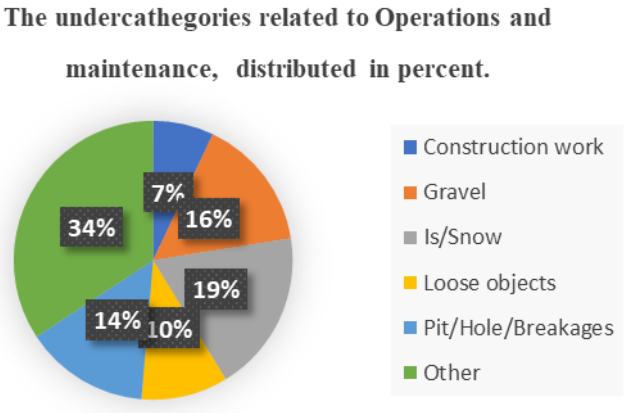

Figure. 18. This pie chart illustrates the causes of single bicycle accidents distributed between different under categories. Those under categories are related to Operation maintenance, in the investigated area in Stockholm, for period 2010- 2016.

The cause for single bicycle accidents related to operation and maintenance are many and varied, thus may in some cases affected each other internally and affected also by external causes as weather condition and the topography (Downhill, Uphill) etc. Additionally, construction work and uneven roads

also appear to be a partial cause of bicycle single accidents related to operation maintenance. Uneven road accident is reported caused by hole / pit / crack on the bicycle path or roadway when bicyclists miss to bicycle around the pit or hole. Some of these subcategories are seasonal, for example accidents occurred due to ice and snow are common in winter and wet leave and gravel on the spring and autumn. It is crucial to know that the cause of accidents could arguably fall in another category, for example some accidents occurred because the bicycle path was too small, and the victim was not able to avoid the ice/leave or pit/hole on the bicycle path. According to Niska et al. (2013b) categorization system, it's still Operation Maintenance that is the main cause in this case.

The municipality of Stockholm is working on investment projects for bicycles with the aim to increase accessibility and road safety including better maintenance of bicycle paths, both in summer and winter (Stockholm, 2018a), Critics point out that the investments are not enough for meeting the increase of bicyclists (Isaksson, 2012; Linde; 2015). There may be some truth in the criticism because accidents in the investigated area have increased during 2010-2016, despite the investments to prevent accidents.

Further, season of the year seems to have an impact on when the accidents occur in this category. Majority of the accidents during period 2010-2016 was during the Spring and Summer (Fig, 19). The accidents n in spring might be because there was still gravel and stones used during the winter months to prevent accidents and that the city of Stockholm had not been able to remove them in time. However, the chart (Fig. 19) shows an even distribution over the remaining months of the year, except winter months when bicycle accidents was less. During the end of the year, there seems to be a larger amount of accidents. This could be because of that the winter begin, which could has result in a lot of skidding etc.

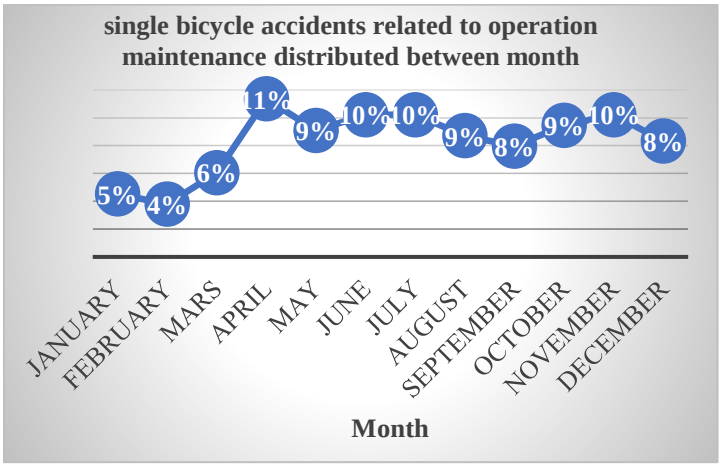

Figure. 19. The chart shows a distribution of accidents that occurred in the chosen area during 2010-2016, in Stockholm. The blue line represented the accidents in percent.

Accidents vary during the day, the result show that the morning was the times accidents occurred the most. It is understandable as in the morning most people go to work, resulting in too many road users on the roads. However, there is difference between the morning and afternoon peak (Fig. 20). The chart shows a distinctive high morning peak that differs from the peak in the afternoon. This difference may be to the fact that most bicyclists have different daily activities and may end it on different times. It could also be that maintenance of bicycle path/road section has not been done yet in the morning before the occurrence of the accidents.

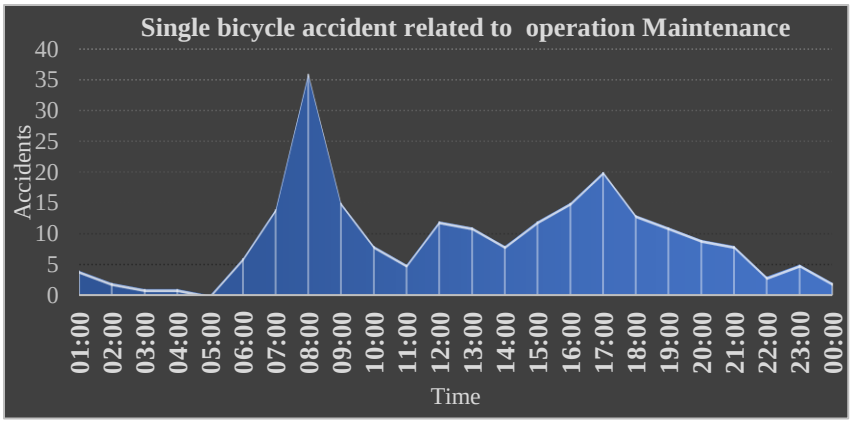

Figure. 20. This chart shows which hour the accidents occurred during 2010-2016 in the chosen area. The blue form shows the number of accidents occurred each hour. The lower the form is the less are the number accidents during that time. Source: Strada.

Furthermore, bicycle accidents were distributed between places where accidents occurred. According to the figure 18, around 49 % of the total single bicycle accidents related to Operations maintenance occurred on Walk/bicycle path and 32% on road section. Intersection has 11 % and sidewalk 7 %. Least accidents occurred on roundabout and square

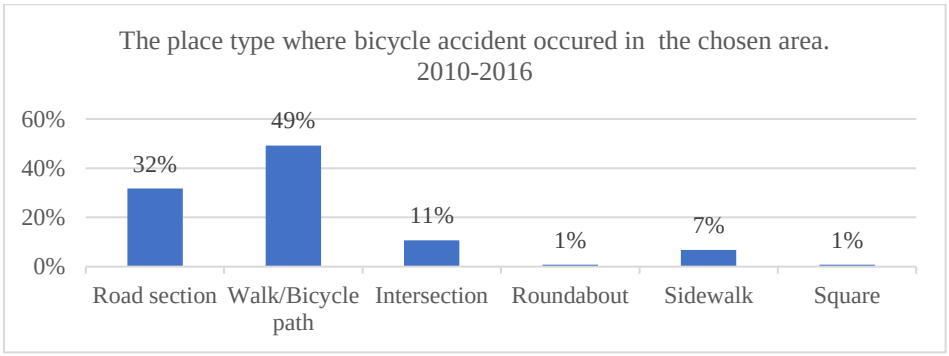

Figure. 21. This chart shows where accidents occurred in the investigate area, during 2010-2016. According to the figure most accidents occurred on bicycle and pedestrians share path.

4.4.2. Bicyclist's interaction with other road users.

Single bicycle accidents related to bicyclists interaction with other road user were the next largest of causes of single bicycle accidents in the main categories and stood for 27 % of all single bicycle accidents during 2010-2016. Along with Operation and Maintenance, they accounted for 55 % of the total single bicycle accidents which is quite large because these two categories represent 2 of 5 categories of bicycle single accidents. The chart (Fig. 22) show a variation in amount of accidents during 2010-2016. When analyse the results presented in the figure, there is no linear trend, rather a more top and down trend. The highest years with larger number of accidents were 2010 and 2016, both years had each part 17 %.

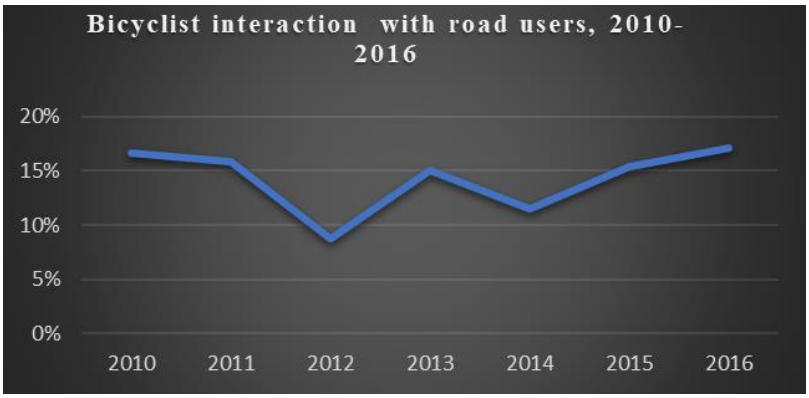

Figure. 22. This chart represents single bicycle accidents related to the bicyclist's interaction with another road users.

Accidents related to bicyclists interaction with other road users were mostly due to swerve for other road users as well as objects that obstruct the accessibility of the bicyclist. Further, the swerving for a motor vehicle (mostly car) either when the car is moving on the road or when someone opens the door of the car. Other swerves occurred on the intersection, when the motor vehicle turned to the right/left and the bicyclist drove forward (Table. 6).

Table. 6. the causes of single bicycle accidents related to the bicyclist's interaction with another road users. The data include accidents occurred in Stockholm between 2010-2016.

Cause of accidents	Number of accidents
Swerved for motor vehicle	105
Swerved for the car door	117
Swerved for bicyclists	42
Swerved for pedestrians	64
Swerved for loose dogs	5
Other	8

Moreover, the amount of accidents occurred in this category was 16 % higher compare with the total of accidents for the whole country in same category (Niska et al., 2013b). The reason may depend on the fact that Stockholm is an urban area with higher traffic flows, as piece of research have shown that most bicycle accidents occur in urban and metropolitan areas (Trafikverket, 2014a; **Stockholm city**, 2016: Niska et al., 2013a).

Most of the accidents in this category occurred on the road section (Fig. 25), which is understandable because the causes of most accidents were due to swerving for motor vehicles and less about swerving for pedestrian and other bicyclists (Table. 6). During the months of the year the months with the lowest number of accidents are December and January and with the highest number of accidents are May and June (Fig. 23). Other important information was that the speed of the bicyclists was not well documented in the STRADA report which hampered the possibility to do proper analysis.

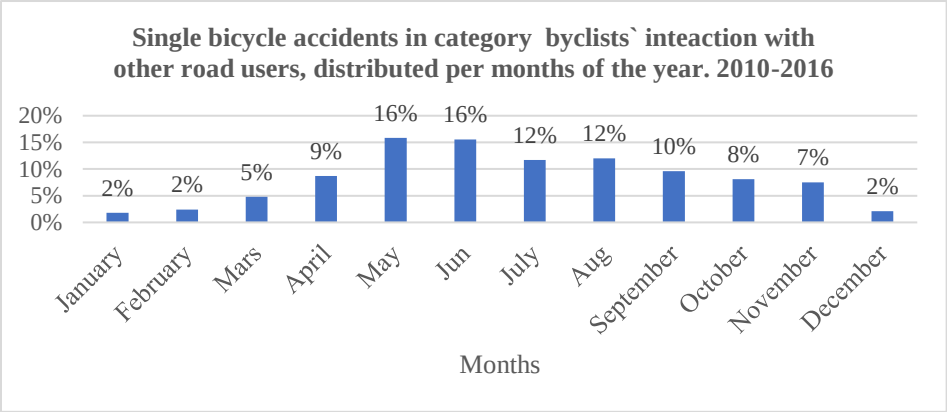

Figure. 23. The bicycle accidents related to the bicyclist's interaction with another road users distributed between months. 2010-2016.

Place and time seems to have an impact on accidents in this main category (Fig. 24. & Fig. 25). The result presented in figure 20 indicate that most single bicycles accidents related to interaction with other road users occurred during the rush hour, i.e. at 8 a.m. and 17 a.m. During this time the figure 20 show two peaks that rise higher.

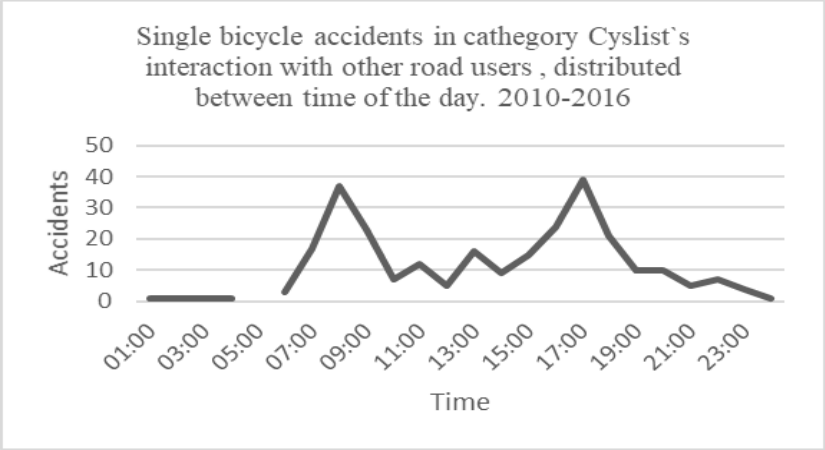

Figure. 24. Bicyclists interactions with other road users.

The result of compilation for places where single bicycle accidents occurred were analysed: 45% occurred on road section and 39 % on bicycle path. Circulation place had less than 1 % of the total accidents and Intersection had13 % (Fig. 25). Conclusion can be made that most of accidents in this category occurred on the road section, which is understandable, as mentioned in this section (Table. 6), the cause of most accidents was due to swerving for motor vehicle and less conflict between pedestrians.

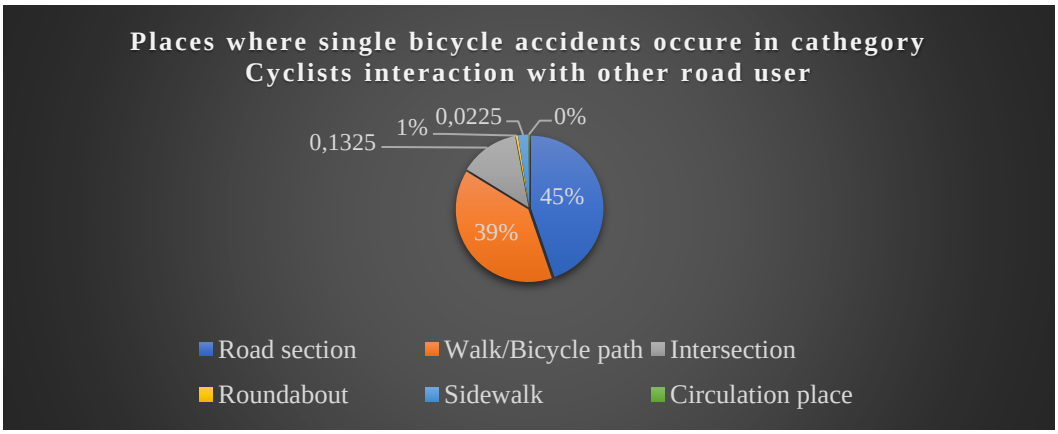

Figure. 25. The single bicycle accidents related to the bicyclist's interaction with other road users distributed between place type.

4.4.3. Road design

The number of single bicycle accidents caused by road design was in total 257 during 2010-2016, which presented for 20 % of all accidents related to single bicycle accidents. There is a varying trend in the number of accidents victims during the year in this main category (Fig. 26), and this complicates the ability to make clear estimates regarding positive change in the number of victims in this category. The number of accidents is comparatively equal in spring and summer times while the number of accidents decreases during winters (Fig. 27).

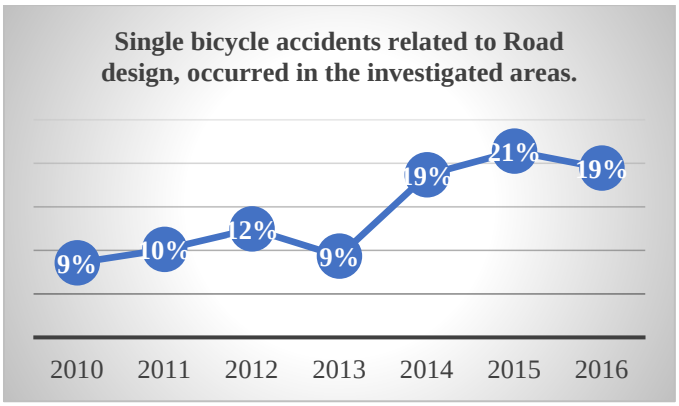

Figure. 26. The bicycle accidents related to road design have increased with 10 % during 2010-2016. The chart indicates a large portion of increase between 2013-2016; during this period accidents emerge with 10 % compare with a modest rise (3%) during 2010-2012.

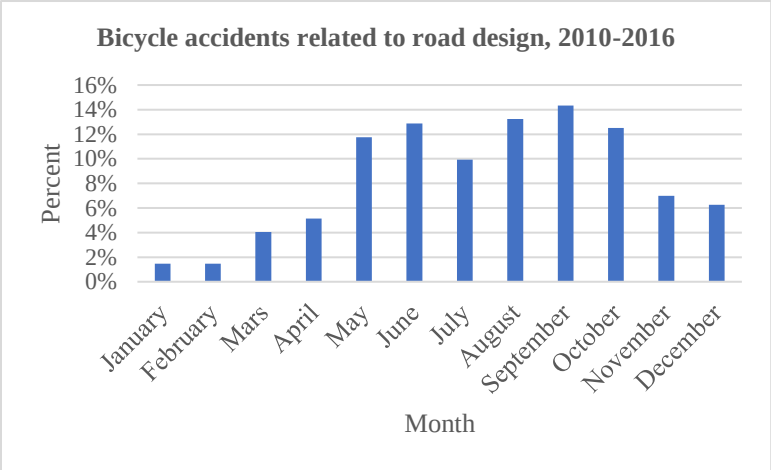

Figure. 27. Compilation of single bicycle accidents related to road design, distributed between months.

In terms of time of day, more accidents occured during rush hour which is quite understandable since it's the time most of the population has 8-17 working hours (Stockholms län landsting, 2016).

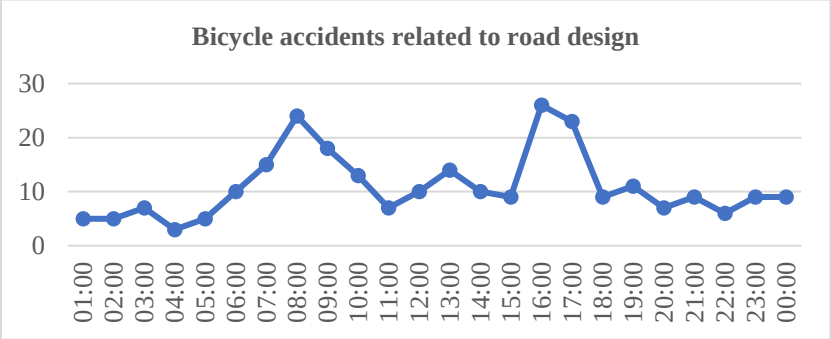

Figure. 28. The bicycle accidents related to category road design, distributed between hour of the day, 2010-2016.

Road design-related accidents are linked to the bicyclists driving on or against a fixed object on the roadway. The sidewalk, curb, refuge and cobblestones are often found in this category as the main cause of accidents. Other solid objects that have contributed to the accident are tramways, road tunnels, wells and even traffic lights. Other victims have pointed out darkness made them miss the curve. Barriers, car cranes and water wells are other factors that have jeopardized road safety for bicyclists, to a lesser extent.

Table. 7. The causes of bicycle accidents that are related to road design, occurred in Stockholm city during 2010-2016.

Cause of accidents	**Number of accidents**
Curb	107
Crowded bicycle path	14
Another solid object	135
Total	257

When distributed bicycle accidents and type of places where accidents occurred, it`s seems that some places have more prone to accidents than other. According to bar chart 24, 50 % of the amount of bicycle accidents related to road design occurred on Walk/bicycle path (Fig. 29).

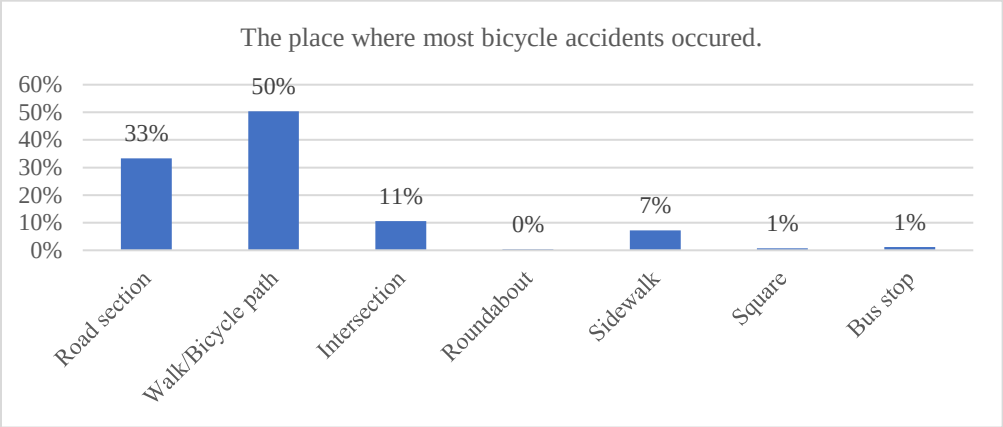

Figure. 29. The bar chart indicates that the majority of bicycle accidents occurred on the shared bicycle and pedestrian's paths. This chart represents the accidents that occurred during year 2010-2016.

However, a lot of information is missing in event description in STRADA, especially about what happened before the victims drives into a curb or other solid objects, information that could be informative in terms of placing the type of accidents in the right category. Niska et al. (2013a) interviews with seriously injured bicyclists in Sweden emerge that road design in combination with an increased bicycle flow on the road led to different actions that led to accidents for the bicyclists. The fact that design of infrastructure is important for road safety, and safety for bicyclists has been able to detect in early research to be beneficial to prevent accidents. Most of today infrastructure are formed for motor vehicle and not bicyclists which create a conflict between different road user. Copenhagen has improved infrastructure in the same way as for motorists and has then improved safety and accessibility for bicyclists, which might be the reason why many bicyclists were more satisfied with bicycling in Copenhagen than in Stockholm in Koglins` (2013) report "2A critical analysis of planning and space".

4.4.4. Bicyclist's interaction with bicycle

The number of single bicycle accidents related to bicyclist's interaction with bicycle was 139 during 2010-2016 and stood for 11 % of the total single bicycle accidents, and for Sweden overall the percentage was 14 (Niska et al., 2013b). The number of accidents related to bicyclist's interaction with bicycle has increased with 13 % during 2010-2016 (Fig. 30) and most accidents happened during summer and less during winter (Fig. 31).

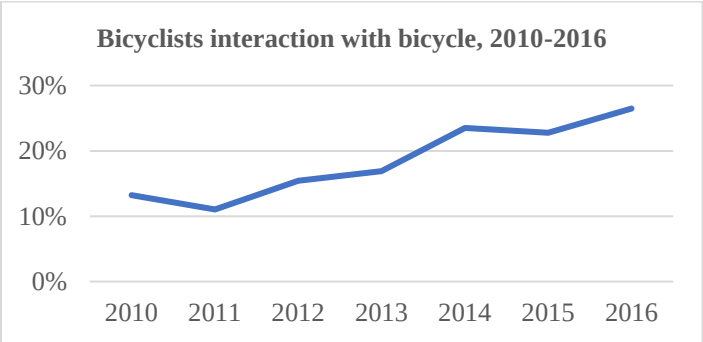

Figure. 30. The bicycle accidents related to bicyclist's interaction with bicycle distributed during 2010-2016.

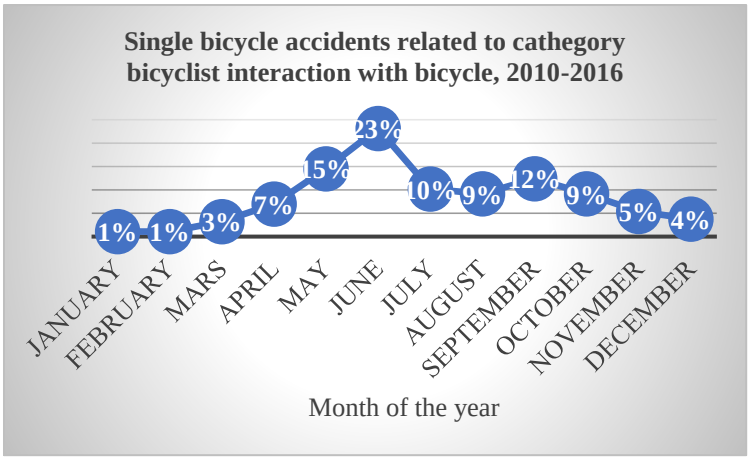

Figure. 31. This figure represents the bicycle accident related to category bicyclist's interaction with bicycle distributed between months. The higher peak indicate that the month of June has highest accident during 2010-2016.

The cause of the accidents in this category was several. Most of the causes were because some type of object (food box, bag, etc.) stuck in the bicycle wheels and thus caused a stop, in some cases, the bicycle brake was inconvenient, or the bicyclist was braking too fast. In other cases, the bicycle chain had gone off or stuck, or when the bicyclist got off the bicycle and stuck with the foot in the pedal and then hit the ground. Bicycle steering and saddle had also been a contributing causes of bicycle accidents related to bicyclist's interaction with bicycle (Table. 8). Based on the result a conclusion can be made that a functioning bicycle is a prerequisite for a safer and safer bicycling for bicyclists and its surroundings as well avoiding to have item on bicycles. These items on the handle can create a suddenly stop in the wheels that the bicyclist is not prepared for and lead to accidents, which was the most common cause of accidents that bicyclist in this category encounter for.

Table. 8. The cause of accidents related to bicyclist's interaction with bicycle. 2010-2016.

The cause of accidents	**Number of accidents**
Bicycle wheel	62
Brake	26
Bicycle chain	17
Bicycle pedal	10
Handlebars	5
Get off bicycle	2
Saddle	2
Other	15
Total	139

Furthermore, certain time during the day and type of places are more prone to bicycle accidents in this main category as well. The results presented in the chart (Fig. 32) indicate that time with highest accidents was 8 A.M and 17 P.M. Regarding type of place, most single bicycle accidents (51 %) in this category occurred on walk/ bicycle path and 33% on Road section, and 12 % on intersection area. Less accidents occurred at Roundabout and Sidewalk (Fig. 33).

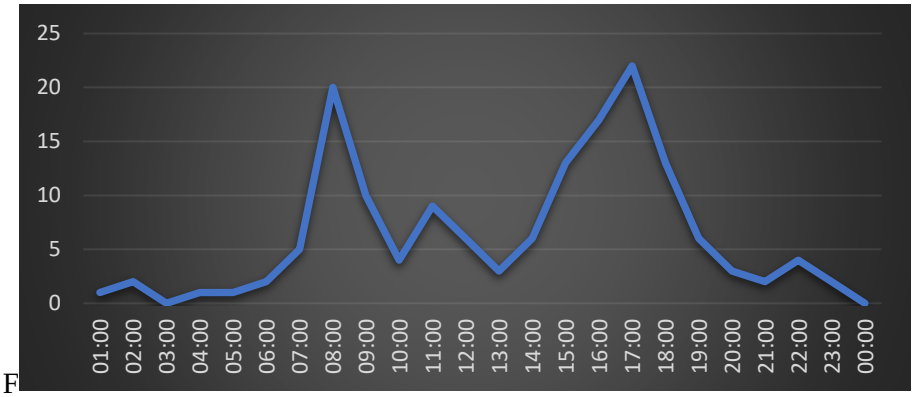

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Figure. 32. Number of accidents distributed in hour show two distinguish peak that are higher than others. Those peaks indicate the hours where accidents occurred the most during 2010-2016 in the investigate area.

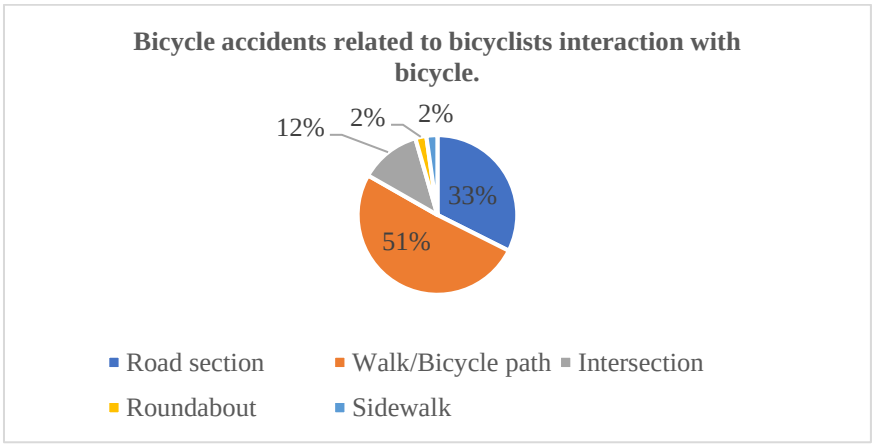


Figure. 33. This chart show place type where bicycle accidents related to bicyclists interaction with bicycle occurred during 2010-2016.

4.4.5. Bicyclist's behaviour and conditions

The number of bicyclists who had been injured in bicycle accidents, related to the category of behaviour and conditions, were 105 and accounted of 8 % of the total bicycle single accidents occurred during 2010-2016. According to Niska et al. (2013b) there were 15% bicycle accidents in this category, in Sweden during 2007-2011. However, during 2010, accidents in this category were quite low, at investigate areas, compared with the years 2011-2016 (Fig. 34). What caused the low accidents in 2010 is hard to predict. The low result of accidents may due to under reporting of accidents in STRADA, or that there were not so many accidents during this year. Another reason may be caused by low bicycle flow. According to Stockholm municipality report of bicycle flow, the number of bicycle passages in 2010 was 4% lower than 2016 (Stockholm, 2018a) and this may be having affected the number of accidents in 2010 as well.

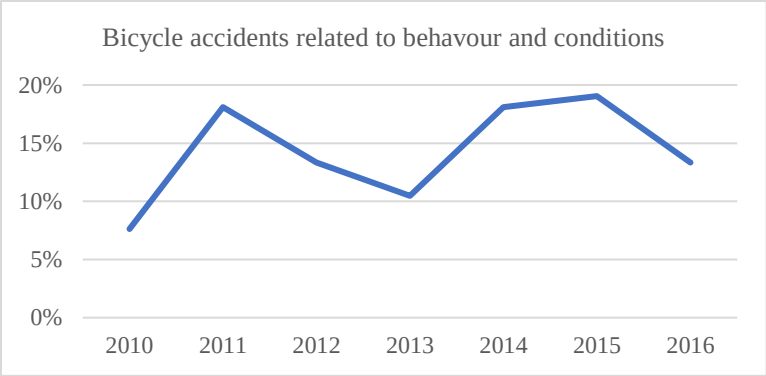


Figure. 34. This figure represents bicycle accidents related to category bicycle behaviour and conditions, distributed between 2010-2016.

During the 12 months of the year, the results of single bicycle accidents related to Bicyclist's behaviour and conditions shows that the number of accidents is much lower in winter than the rest of the season, and in February there have been no accidents at all. Most accidents have occurred in the summer and spring and autumn and summer. The month with highest accidents were June and July (Fig. 35).

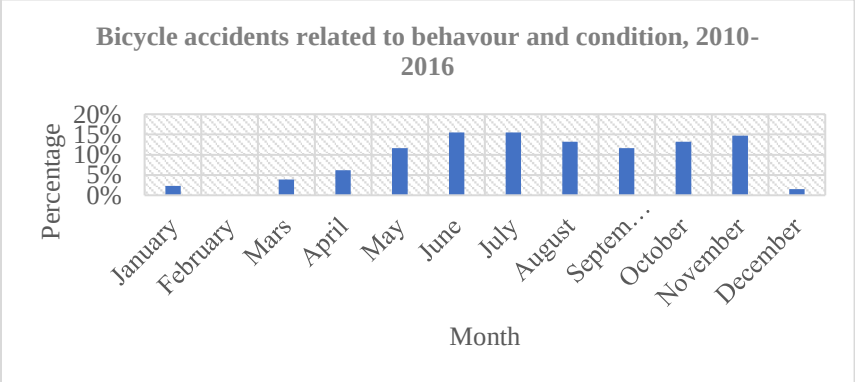


Figure. 35. The bar chart represents bicycle accidents related to category bicycle behaviour and conditions, distributed between months. 2010-2016.

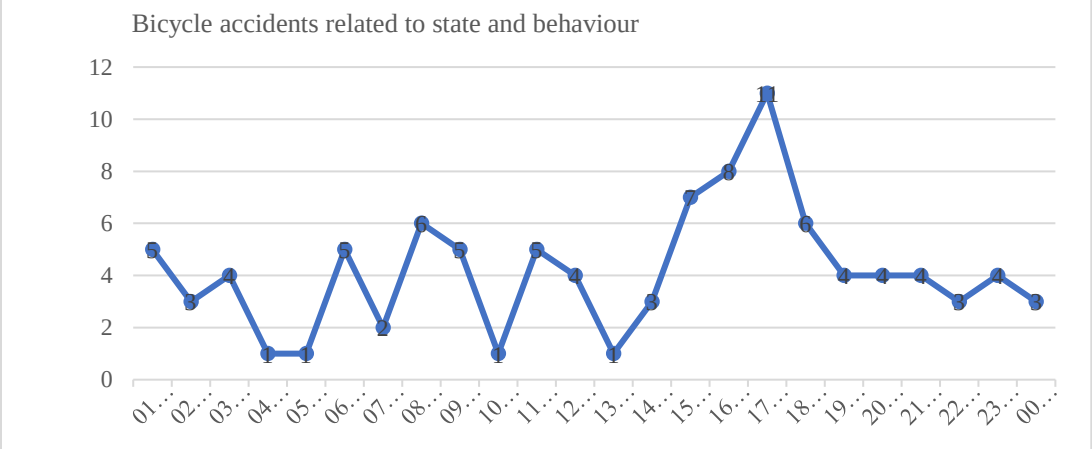


Figure. 36. This chart represents the bicycle accident related to category bicycle behaviour and conditions, distributed between hour. 2010-2016.

Moreover, the result of accidents that occurred during the hours show an unstable ups and down pattern from 1a.m -13 p.m. The chart shows that after 13 p.m. the line in the chart stability increased, without

turning down, and reach the highest value at 17 p.m. and after that the line decrease again. The line chart shows also a high number of accidents during the night (Fig. 36).

The cause of accidents in the category bicyclist's behaviour and conditions are several. Some of the bicyclists have given high speed as the cause of accidents and other indicated the using of the Mobil phone as the cause of accident and picking up stuff in the pocket. Other causes were having dog on dog leach while bicycling as well as taking the wrong decision on road (Table. 9).

For the conditions it was alcohol that had the highest number of accidents followed by bad balance and lack of attention. There were also some accidents that happened without external caused and these were placed in this category because there was no indication in the description which indicated that these accidents were caused by external factors as the bicyclists fell without knowing why (Table. 9**).** The STRADA report was also inadequate in terms of speed: only a few numbers of accidents were reported in the Excel column for speed. Majority of Excel cells in the column were empty and some few contains unknown speed. The high speed mentioned in this section were found in the written event description in Strada report. Other large amount of accidents that has included here were the accidents with unknown cause.

Many critics of how bicyclists behave on the roads mean that bicyclists get away easily when they violate traffic rules compared with motorists. Of the reported traffic rule crimes in Sweden, only motorists suffered more severe punishment, but the bicyclist escaped with low fines or released completely (Björklund et al., 2016). It can encourage bicyclists not to take responsibility to ensure that they bicycle safely, not just for themselves but also for other road users. Information about traffic rule and behavioural change to bicyclists can have some positive impact for the occurrence of bicycle accidents in this category.

Table. 9. The cause of accidents related to bicyclist's behaviour and condition.

Behaviour	
High speed	28
Low speed	3
Wrong decision	3
pick something in/out pocket	5
Talked on the phone	7
Dog on dog leash	5
Bicyclist`s conditions	
Bad balance	8
Alcohol	10
Lack of attention	4
Waved	5
Unknown behaviours and conditions	27
Total	105

When distributed bicycle accidents between type of place where accidents happened, it`s seems that some places was more prone to accidents than other (Fig. 37).

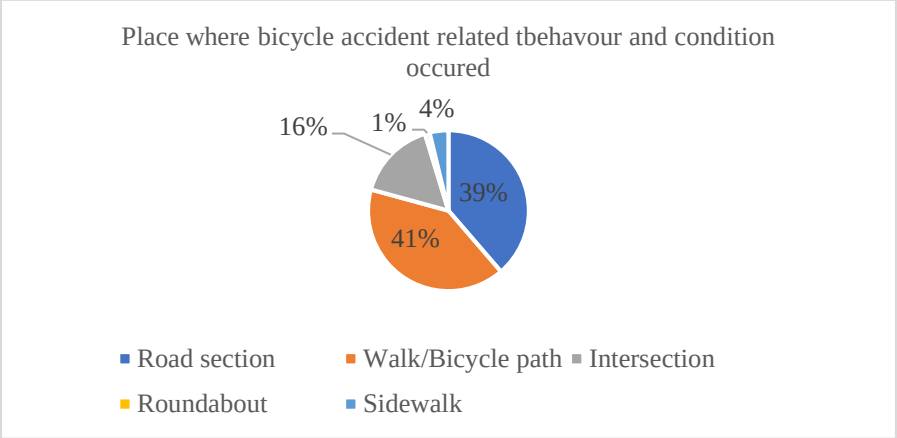


Figure. 37. The bar chart represents the bicycle accident related to category bicycle behaviour and conditions, distributed between place type where accidents occurred during 2010-2016.

4.4.6. The single bicycle accidents distributed between time

Further the total (1277) number of bicycle accidents were distributed between time (Fig. 38 -Fig 40). The result show that the amount of single bicycle accidents has increased by 8% in 2010 – 2016. Accidents have increased by 1% between 2010 and 2013 but between 2013 and 2014, the proportion of accidents increased by 3%, which is twice as much compared to the rate of increase between 2010 and 2013.

Further, while single bicycle accidents have increased with 8 % during period 2010-2016 bicycle flow in the investigate areas (section 2.4) has increased with 4 % during the same period. These results indicate that bicycle accidents increased faster that bicycle flow and if this trend continue less people may stop to bicycling, which could counteract the municipality's` goals to increased bicycles with 15 % during rush hour (Firth, 2012), the time most accidents occurred according to the result of study (Fig. 39).

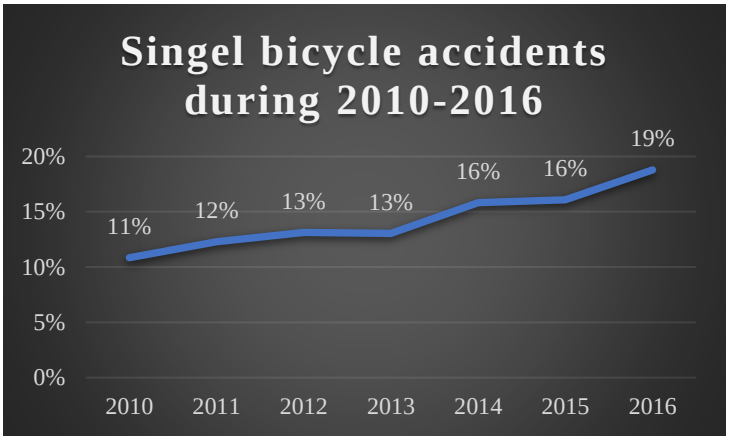


Figure. 38. The total of single bicycle accidents distributed in percentage.

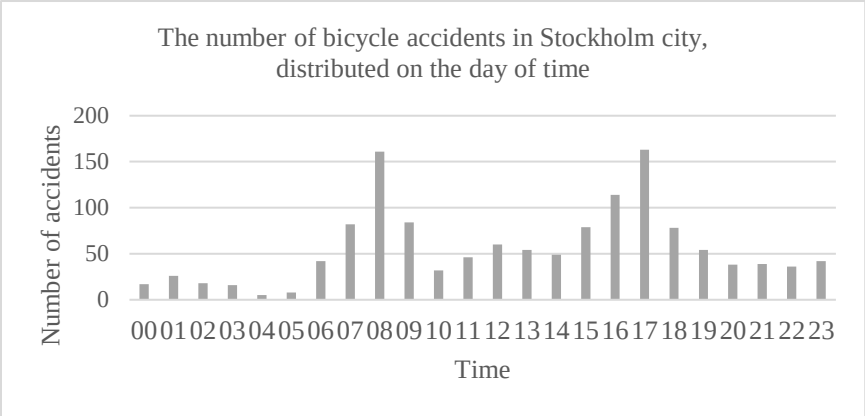


Figure. 39. This figure represents all single bicycle accidents occurred in Stockholm, 2010-2016, distributed between hour. The result shows that majority of the accidents occurred during rush hour.

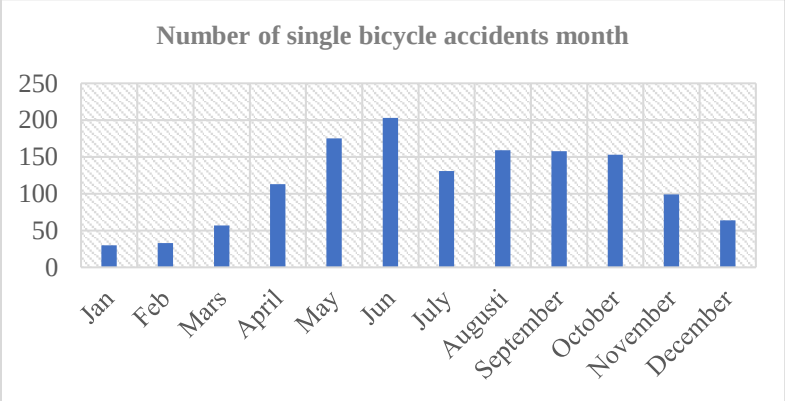


Figure. 40. This figure represents the numbers of single bicycle accidents are presented. Those are the total accidents that occurred between 2010- 2016.

Single bicycle accidents were higher in May and June (Fig. 40), the pattern can be shown on bicycle flow at Munkbroleden (Fig. 7). However, bicycle flow for the measurement station Strömsbron show another pattern; in August bicycle flow measured at this station was higher than the number for July and June (Fig. 6). This trend indicate that the number of accidents differ on different place in the investigate areas, though the results raise an important reflection about whether there is a correlation between bicycle flow and bicycle accidents. Based on these results I can conclude that there is a pattern/correlation, even though the amount of bicycle flow and bicycle accidents differ monthly, but just because there might be a correlation between number of bicycle flow and the accidents does not mean that the correlation is the cause of accidents.

4.4.7. Bicycle accidents occurred during the night

Furthermore, number of accidents during the night were 104 during 2010- 2016 (Fig. 41). Of these, 50 were road design related. Men at the age of 30 were overrepresented. Causes of accidents during the night were mainly due to bicyclists driving towards the sidewalk or fixed objects on a bicycle path or road section. Its appeared on the event description that more than 52 bicyclists were drunk. Another interesting notice was that the number of accidents occurring during the weekend (Fig. 42) is greater than during the day of the week which can indicate that bicyclists` behavior may have been decisive for the occurrence of an accident. At that time during the week, most people are out, and the consumption of alcohol is higher than during the day of the week. In conclusion, a combination of intoxication and darkness as well as road design were the most causes of accidents that occurred during night time.

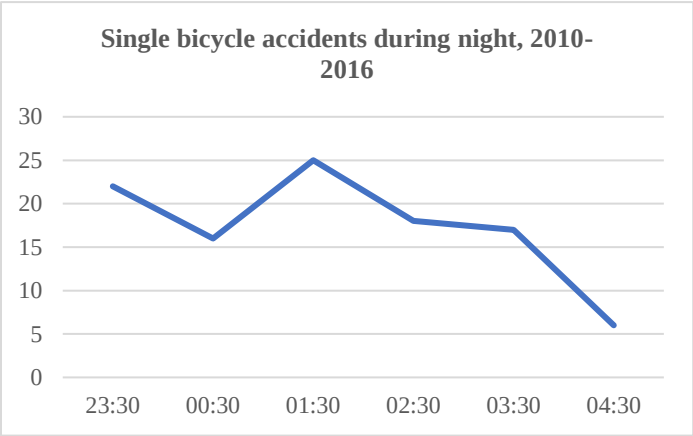


Figure. 41. The number of single bicycle accidents occurred during the night.

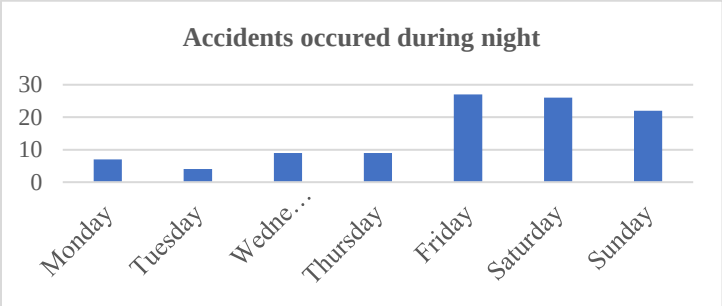


Figure. 42. Single bicycle accidents occurred during the night distributed between week day, 2010-2016.

4.4.8. Single bicycle accidents based on sex and age

Gender and age were analyzed. Men are overrepresented in single bicycle accidents.

Table. 10. Gender distribution between the number of bicyclists who have been involved in bicycle single accidents in Stockholm, 2010-2016.

Gender	Percentage
Man	57 %
Woman	43 %
Unknown	0 %
Total	100 %

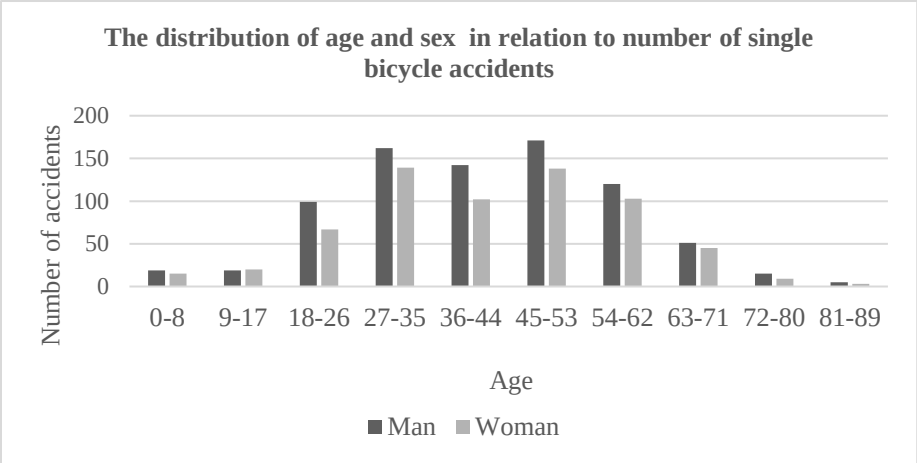


Figure. 43. Distribution of number of single bicycle accidents between age and sex. The accidents happened in Stockholm city center between 2010-2016. The age group was grouped with 9 years intervals.

4.4.9. Use of helmet

Strada report contained information about the use of helmet when accidents occurred: In the report the bicyclists had answered yes or no if helmet was used at the time of accidents. The result show that majority had helmet (Table. 11), but 14% of the total single bicycle accidents hadn't information about the use of helmet.

Table. 11. The number of cyclists that had helmet on at the time of single accident during 2010-2016.

Use of helmet	Percentage
Yes	57 %
No	29 %
No information	14%
Total	100 %

5.3.10. Bicyclists Injury grade

To get an idea of how seriously injured the bicyclists were after the accidents, a manual examination of the number of injured was done, based one Strada categorization which can be found in Chapter 3: Accidents classified as minor have ISS 1-3, moderately injured have ISS 4-8 and seriously injured have ISS 9-. As mentioned in chapter 3, ISS is a summary of all injuries on the body and indicates by Emergency Medical Care (EMC) to categorize the risk of the person's ability to survive his injuries (Howard & Linder, 2014).

The injured grade was well organized in the Strada Excel file, which facilitated the work. The result (Table.

12) showed that most of accident victims had minor injuries. Of the 1277 bicycle accidents that occurred in the investigate area, there were 731 minor injured, of which 116 of them came from the police report. Furthermore, 465 were injured moderately and 45 had severely injured. Of the 45 severely injured, there were 27 bicyclists hospitalized for more than 24 hours, and the majority of severely injured were due to operations maintenance (17) and bicyclist interaction with motor vehicle (11). In addition, 27 of severely injured had helmet at the time of accidents while 12 did not wear helmets. There were also 30 bicyclists who didn't injured physically.

Table. 12. Number of single bicycle accidents distributed between different category of injuries.

Injurie degree	**Number of accidents**
Fatal accidents	5
Severity injuries	45
Moderate injurie	416
Minor injurie	731
Other	30
Total	1277

4.5. Qualitative interview

Qualitative interviews with 25 bicyclists (informants) conducted in 2018, with the purpose of getting information about bicyclists' experiences of bicycling in the investigated areas. This was done as a complement to the cause of single bicycle accidents written in Strada event description.

However, all informants in the interview were informed that participation was voluntary and that their identity would not be revealed. The interview was made with only bicyclists who bicycled in the investigated area during 2010–2016. Interviews were made by telephone or by answering questions in the interview guide and email to me. The interview questions in the interview guide are taken from Niska et al. (2013b) report, as I found that their interview questions went aligned the purpose of this study, and due to the limit of the time I had, it was considered the best option.

The informants age varies between 20–83 (some informants didn't give their age), and the gender is mixed, with a slightly higher proportion of men, but I think this has not affected results since all informants had a broad view of how it was to bicycle in the investigate area that time.

Furthermore, the interview guide was divided into 8 sections and the first section contain background of the informants, followed by the 7 other sections focusing on road design, interaction with other road users and suggestions for measures that can improve the safety and accessibility of bicyclists in the traffic.

4.5.1. Bicycling habits and why the main cause of using bicycle

All informants who participated in the study had bicycled for more than 10 years. Environmental awareness and physical exercise, indicating 90% of the informants, were the main reason for choosing bicycle as a means of travel.

Some informants had other reasons like crowded Stockholm city and difficulty to get a parking lot:

"It's no good idea to have a car, there is always a problem with parking and there is always trouble with queues, it's so crowded in town" (Man 53).

Furthermore, another informant pointed out about health benefits and the flexibility with bicycling:

"Prefer to be out in the days - even the possibility of daylight in the winter. Make it easy to move between places" (Woman).

The reasons why all informants start bicycling are many and differ sometimes from each other but the majority bicycle mostly because environment awareness. Informants bicycle daily to and from work, but only 50% of the informants stated that they bicycle all year round. The length of travel for all informants varies between 3-20 km.

4.5.2. Road design

Regarding the question about informants' experience of bicycling in Stockholm city, 90% informed that they felt that road design in some places in the investigated areas makes accessibility difficult and creates traffic jams and unnecessary conflicts between road users, especially at crossings:

An informant tells:

" Götgatan / *Hornsgatan (see section 4.5.3); The crossing is incredibly poorly designed so that when there is green for bicyclists on Götgatan to go forward, it is also green for the pedestrian, and most bicyclists on Götgatan will turn right, because the number of bicyclists can be like 80 at that crossing, and those who turn right will stop all the traffic for those who are going straight up and those who are going straight up will not get straight and those who will turn on the right will not be able to do that because the pedestrians are in the way "* (Man 29).

Another informant problematizes and points out that the bicyclists are the group with the most heterogeneous road users and that road design is not adapted to it:

"Bicyclists need to be able to bicycle around each other everywhere if it's feasible because they constitute the most heterogeneous road users with speed differences of several hundred percent. And the speed differentials should be several hundred percent - which means that both elderly, children, those that use bicycle with 10+ km and others can use the bicycle" (Man).

Another informant agrees in terms of bicyclists as a heterogeneous group and explains problems that may arise when different bicyclists at different speeds meet each other:

"You feel insecure because of crowded space and bicyclists driving too fast. Biggest problem is with other bicyclists. Bicyclists today are bicycling too fast. They bicycle by overtakes me too fast " (Woman 83).

Security appeared to be important to all informants during interview. Women expressed it more clearly than men by using the word unsafe during the interview, about places and situations on the road, that jeopardized their security. Men on the other hand, used word as “problems” instead of “unsafe”, Although, all informants pointed out that transport system is more suited to motorists than bicyclists, and this seems to be problematic. An informant said:

”There is a bicycle path that crosses driving lanes, for example outside the central station, it is a such a scary place; you are on very right on the road and bicycle along Vasagatan and then when you reach the central station and want to continue towards Gamla stan, then the bicycle path crosses two driving lanes so it's crazy. I do not understand how one can build the bicycle path in that way, because it is always the risk of life when you bicycle there. " (Female 53).

Regarding the question about the informants' experiences of bicycling on paths shared by both pedestrians and bicyclists, there were many who had negative experiences about bicycle on the shared path with pedestrians:

"It's about being too crowded, pedestrians walking on bicycle path, and to end up in a disadvantageous position at intersections where swinging cars pose a danger, and that there are cars that are parked on the bicycle path or other obstacles in the way. Choosing the roadway eliminates all these problems " (Man).

Another informant added:

” Pedestrian and bicycle path are a remarkable hybrid. Choosing to mix Bicycle traffic with pedestrians, often without sensible separation, is not good. Why not mix buses and pedestrians instead? " (Man).

The discussion went further to actions that Stockholm City had made to promote bicyclists` safety. And most informants experienced that some actions created even more security issues rather than fixing them. Particularly designated are the red marked bicycle files on the roadway; many informants stated that its seems like many motorists think the red files are built for them. One of the informants tells about her experience of bicycling on the red marked bicycle file:

"There are few drivers who seem to know / pay attention to the red-marking and less visible bicycle file (Woman 37).

4.5.3. Accessibility

When informants were asked about how it was to bicycle at different times of the day, many of them experienced that the rush hour had poorer accessibility at some places in Stockholm city, and that narrow bicycle paths were partly:

"There are so many bicyclists, especially at Götgatsbacken early in the morning. It's so crowded, and not easy to drive forward with bicycle, but after 9 then there are not as many bicyclists " (Woman 60+).

Another informant did not fully agree with the previous informant, and acknowledged that the rush hour could be difficult but most of the time bicyclists had better accessibility than motorists:

"It's good accessibility during all hours. The bicyclists always find a way to over drive forward and never end in queues. The traffic is a little messy during rush hour, but it's only marginal to be affected by as a bicyclist. " (Man 55).

Furthermore, the discussion changed to how it was to bicycle during different seasons. Many experienced that winter time was better for bicycling as there were few bicyclists during that time, but on the basis that anti-slip was performed. Although most informants think the summer is the worst to bicycled on:

An informant said:

" When it's starting to get nice weather and all bicyclists come out, there can be some challenges. Then you must structure with everyone else. I do not like when cars drive by, it feels uncomfortable" (Female 53).

4.5.4. Interaction with other road users

Overall, informants, at the time of the interview, mentioned that most of all road users (bicyclists, pedestrians and motorists), could manage to behave well in traffic, but at the same time they also pointed out that there were those among road users that did not behave well. Those that were not behave well were firstly bicyclists secondly motorists and thirdly pedestrians. In the case of bicyclists, some informants could observe that many bicyclists were taking unnecessary risks on the road.

It was clearly during interview that different informants experienced different situations with different road users under different circumstances: Some of informants experienced less conflicts with pedestrians but more with motor vehicle and other informants had reversed experiences.

An informant said:

"The worst thing I know is bicyclists who behave like these motorists. It is seen from time to time. They drive hard against poor pedestrians who have forgotten that they go on the bicycle path. A bicyclist comes and tingle, they do not think so, they are out in their photographs and stuff, bicyclists are driving next to them, as well as showing that I have the right to bicycle here and you are not allowed to go here, and unfortunately I think it's a proportion of bicyclists who have increased unfortunately, but I do not think it's a big problem with pedestrians' (Man 29).

Another informant agrees with the previous informant and condemned the behaviour of bicyclists, by pointing the bicyclists ruthless against pedestrians:

"*bicyclists rush over unattended junctions, or slalomed close to pedestrians, it is unpleasant, and it does not facilitate the interaction between bicyclist and pedestrian in the long term "* (Female 20+).

Other informants found it easer bicycling among motorists than bicyclists, and did not experience conflicts with pedestrian, rather other bicyclists:

"*The interaction with the motorists works better, the motor vehicle is moving forward while bicyclists tend to bicycle slowly, they wander and do not look around. No problems with pedestrians. I prefer to bicycle in mixed traffic* " (Man 40+).

Furthermore, an informant discusses how frustrated it was when she occasionally tingled to some pedestrians who walked on a bicycle path, and instead was aggressively treated because she tingled to get their attention:

"*People are aggressive in society and I do not understand why. I'm like this, I tingle, and most people are happy and say thank you for tingling, I'm tingling out as well as when I'm going to bicycling a*

bicycle and make pedestrians pay attention to my coming, but some people get angry of it " (Woman 50+).

4.5.5. Bicyclists behavior in traffic

When the discussion went on to dealing with bicyclists' behaviour in traffic, some informant complained that some bicyclists take the risk when they hang on items by bicycle, and that many bicyclists break the traffic rules. Breaking traffic rules, according to some informants were inevitable because the traffic system at some places in Stockholm urged many bicyclists to create their own traffic rules to have good accessibility. In other words, they broke against traffic rules because it was safer for them to not wait for the green light:

"*I am usually against red light, because I cannot wait, but at a great crossing, I'm waiting. Otherwise no, I do not think there are any problems with traffic lights, the green and red intervals are reasonable, you must be street smart, you can bicycle when there are no motor vehicles, I will take the chance, it's logic "* (Man).

"I do not really know, I think bicyclists do not care, many bicyclists are not careful, they hang the cashier on the board, they wrap up, they do not look around, they often look down, I wonder why they often look down. The look at the feet, they look at the chain that spins " (Man 53).

"It happens sometimes, and I have understanding for those who bicycle when red light, in some places it is dangerous to not do it. For example, Långholmsgatan's bicycle paths are to the left of the bus stop, it turns green for the bicycle that will appear while green for swinging buses, so you must choose to drive towards red or get hit by a bus (Female 60+).

4.5.6. Operation and maintenance

In terms of operation and maintenance, experience among informants differed and this could be that informants bicycle on different place and at different time, and the different streets might be in different condition at the different time. An informant told of his experience of snow ploughing in winter:

"Very varied - can be absolutely fantastic at Skeppsbron but terribly bad a few blocks away on Birger Jarlsgatan." (Man).

On the question of the extent to which operation is concerned, maintaining their ability to bicycle in winter, many experienced that it was difficult to bicycle during the winter, when it is cold and dark, especially if snow ploughing has not been performed; road signs that separate bicycle and motorists could disappeared and motorists would drive all over the places including at bicycle file. The area with high number of road users, for example where bus stops are available, was hard for bicyclists to get good accessibility. Despite the negative experiences, most informants found that winter road maintenance has improved, especially the saline salt method used on winter was appreciated:

" Collected snow alongside the motorist roadway are another problem. As mentioned before, winter road maintenance has become much better in the last years, mainly due to saline salting. Traditional snow ploughing leaves a lot of slush, which eventually becomes worn and then, in 9 cases of 10, is freezing and becomes ice-capped. Which is one of the worst basis for the road. Even the slush itself is difficult to take off" (Man).

Further, some informants found that the salting method was excellent as it prevented rolling of gravel in the spring. But at places where the traditional snow removal was used, it took time for the municipality to remove the gravel:

"In the spring, the biggest problem is all rolling gravel that has remained after traditional snow removal. Those roller gravel cause slippery, the same way as snow & ice. And the road keeper considers sand removal as a cleaning and does not understand that it is necessary to remove the roller gravel as it should consider as slippery prevention. You cannot, as the Stockholm Traffic Office and the Swedish Road Administration do, wait until the "season is over". Rolling gravel on asphalt must be removed as

soon as the snow cover is smelt off. Even if it means that you may have to sweep again after the next snowfall. No more strange than that you have to plough after every snowfall - you cannot wait until the "season is over" to make sure you do not have to do it again " Man

When it comes to advertisement on roads, some found that in some places, reparation was not done: An informant says:

"Repairs in the asphalt is strikingly often uneven. Some newly built bicycle path (e.g. Sveavägen north side, between Sveaplan and Norrtull) are strangely bumpy and "wrinkled" (Female 25).

Some informants also mentioned pit on the roads and risk with these:

"A risk factor is pits on roads as there is a risk of driving straight into it, unless you are noticed" (Female 34).

4.5.7. Measures to improve traffic safety and accessibility for bicyclists

Regarding the question of what measures that would be appropriate to apply to increase safety and accessibility for bicyclists, many informants suggested rearrangement of bicycle path by broaden them, create new bicycle path as there are more bicyclist, and also replace the curb with line, especially at Skeppsbron. Others also proposed identifying traffic-hazardous solutions that exist (such as at Vasagatan, for example) and rebuilding them. All informants thought that saline salting in winter instead of traditional snow removal was a better alternative in winter. Other suggestions were physical separation from pedestrians and speed reduction to 30 / km in urban areas, as well as learning bicyclists to pay more attention in traffic, this would reduce bicycle accidents. Further, the informant pointed out which place were not safe for bicyclist to bicycle at and these were: Götgatan/Hornsgatan, Södermälarstrand. Sveavägen, Vasagatan Liljeholmsbro, Fleminggatan/St Eriksgatan, Skeppsbron, stadshuset, Odengatan, and horsntullsbron.

4.5.8. Stockholm City's efforts to improve safety and accessibility

Many thought that the city of Stockholm, together with other authorities, is getting better and better in their efforts to increase safety and accessibility for bicyclists, on the other hand, criticized them for lumping together bicyclists with pedestrians, many believe that this is one of the reasons why the safety of bicyclists and security is moving slowly and not as quickly as desired. The fact that bicyclists are not considered as their own road user group / vehicle means that the measures taken to improve the bicycling are not sufficiently adapted to the bicyclists. If considering bicycling as a vehicle, the measures to increase safety for bicyclists would have been different than they are today. An informant thought:

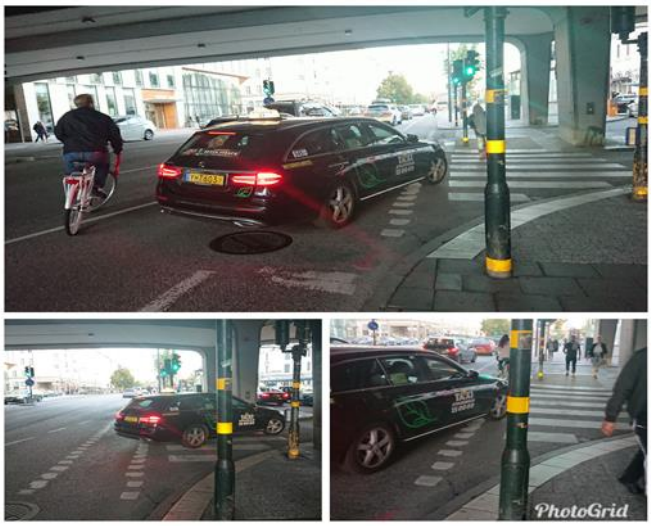
"However, there is still an idea that bicycle traffic is not "real" Traffic, which means that there are always exceptional solutions, insufficient resources and sites. Only when you really consider a bicycle as an equal traffic with motor vehicle and public transport then the change will be made. This way of thinking still reflects the 15th thought of lumping together bicyclists and pedestrians. This is proven on the Facebook Stockholm Traffic Office, where bicyclists and pedestrians have lumped together, why not lump the subway and motor vehicle too? " (Man).

4.5.9. Inventory

During the qualitative interviews about bicyclists' experiences of bicycling in Stockholm city, some of the informants could point out places in the city that they found to be risky for bicyclists. The places mentioned included Götgatan/Hornsgatan, Sveavägen, Vasagatan and Liljeholmsbron. The purpose of the inventory was to get a picture of and experience on how it is to bicycle in the investigate areas. Bicycle, camera and measuring tape were used as the tool for inventory. The results of the inventory are presented below.

4.5.9.1. Vasagatan

These three pictures are taken at Vasagatan on August 17th, 2018 at 20 p.m. The reason why this area was observed was because some informants during the qualitative interviews mentioned this place as one of the most dangerous places for all road users, in particular for bicyclists. The road contains 3 lanes and the bicycle path is on the right side of the road. When the traffic signal turns green for bicyclists and vehicles to drive towards Gamla stan or turn to the right at the Central Station, the vehicles that turn to the right at the central station block the path of bicyclists that want to drive forward to Gamla stan. This situation may force bicyclists to drive on the road section, as it appears in the picture below where a bicycle chooses to drive on the road section. At the same time vehicles get green light, the pedestrian crossing turns green as well, and force the vehicles that drive in the entrance to the Central Station to wait and stop all bicycle traffic on bicycle path to drive forward.

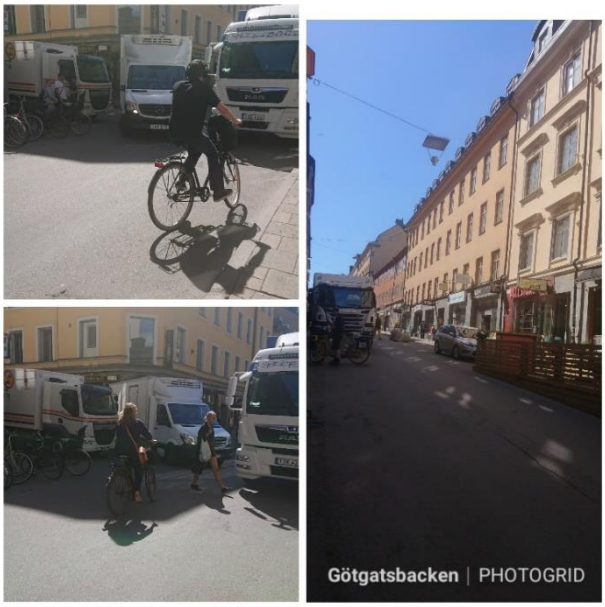


4.5.9.2. Sveavägen

These pictures are taken at Sveavägen. The width of the bicycle path is 115 cm, the bicycle path is on the right side of the road section and between the bicycle path and road sections there are vehicles parked alongside the bicycle path. When bicycling on this bicycle path during inventory, the path felt narrow and bumpy, uneven and had cracked asphalt, as it appears on the picture above. The investigation was made in 31 July 2018.

4.5.9.3. Slussen

These pictures below were taken at Slussen on May 8th, 2018 at 11 a.m. The main cause of taking pictures was to observe how bicycle traffic is at Götgatbacken and Götgatan/Hornsgatan. According to pictures and my own observation, the accessibility and safety for all road users, especially for bicyclists was poor at the time of investigation.



4.5.9.4. Liljeholmsbron

The picture below shows double bicycle paths, 250cm width, that facilitated for bicyclists to bicycle against different directions.

4.6. Analysis of qualitative interview and inventories

In conclusion, based on the informants' subjective experiences of bicycling in Stockholm city, and the inventory made on some areas that the informants pointed out to be unsafe places to bicycle at (section 4.6), a conclusion can be made that there is more to do to improve bicycle safety and accessibility in investigated areas. Stockholm municipality's approach to prevent bicycle accidents is consistent (Trafikverket et al, 2014b; Stockholm, 2018d) but more resources are needed to increase safety and accessibility for bicyclists in Stockholm. One of the improvements could be to rebuild the bicycle infrastructure to increase its capacity to fit the number of bicyclists on some places in the investigate areas, as some traffic solutions are creating more issues between all traffic users rather than solving the issues. Copenhagen's investment in bicycle infrastructure has been shown to be successful in terms of accessibility and safety (Högström, 2009). A report on how bicyclists experience the traffic situation in Stockholm and Copenhagen showed that bicyclists in Copenhagen were more satisfied with how it is to bicycle in Copenhagen than bicyclists in Stockholm (Koglin, 2013).

However, the qualitative interview with bicyclists (informant) also showed that all bicyclists were not satisfied and that their experiences of bicycling in the investigated areas differed. Arafi (1999) points out that the experiences of a place are subjective and shaped by different factors**,** such as cultural values, gender, age, economic preferences, experience and professional backgrounds etc. It was clear during interview that men took more risks than women when they faced some challenges on the road. Besides, bicyclists are a heterogenic group with different speeds and because of narrow bicycle paths at some places with a high traffic volume, the conflicts emerged when different speeds met, and when space was lacking, which made it more difficult to bicycle. Conflict occurs because bicyclists' accessibility and security are limited by other road users and by some traffic solutions, i.e. traffic lights and road designs in the investigate area. According to Harvey et al. (2005), reactions of this tension and conflict lead to different individuals using their power to guard themselves against others and these conflicts between different individuals lead to separation between different individuals, which some informants mentioned during interviews that there was conflict between bicyclists and other road users which resulted in insulting and physical abusement.

Regarding traffic lights and traffic solutions, other conflicts could emerge at some places like Vasagatan in front of the central station (section 4.6.1.). This traffic solution may force bicyclists to drive on the road section as it appears on picture 4; while vehicles get a green light, the pedestrian crossing turns green as well and force the vehicles that drive into the entrance to the Central Station to wait and stop all bicycle traffic on the bicycle path to drive forward. These kinds of traffic solutions could create conflicts between road users and prevent accessibility for traffic users, especially for bicyclists.

According to the Stockholm Bicycle Plan (2014), commuter lanes for bicyclists must be at least 2.2 5m wide for one-way bicycle paths, and 3.25 m wide for double lanes, but during the inventory, it was found that Sveavägen was 1.65 m. Bicycle paths at Liljehomsbron was also smaller than recommended in the Bicycle plan. According to the recommendation in the bicycle plan, a double way bicycle path should be at least 3, 25 m and at the time of the inventory Liljeholmsbro double way bicycle width was 2.5m. Inventories confirm the informants' experiences about bicycle infrastructure in the investigated area.

Furthermore, in terms of operation maintenance in Stockholm city, many interviewees experienced that it was difficult to bicycle in winter, especially when it was cold, dark and snow ploughs have not maintained roads, which can lead to confusions as road signs that separate bicyclists and motorists could be covered by snow, and motorists could drive into bicycle paths. Operation maintenance is, unfortunately, the category that had highest accidents reported in Strada in the investigate area (section 4.4).

However, despite the negative experiences, most informants found that winter road maintenance has improved, especially the saline salt method used in winter which was appreciated because the saline method also lead to less gravel during the spring when compared to traditional snow removal where gravel is used, as these rolling gravels could cause skidding the same way as ice and snow. Other

problems with the operations maintenance were pits and cracks on the road, thus potentially leading to an accident when bicycling onto these.

Finally, it appeared that there is a need for change to improve bicycling infrastructure. The change is not just needed among road users, but also among those that create traffic flows as well as those that implemented it. Many informants thought that bicycle traffic should be treated as a separate traffic group, thereby not lumping it together with pedestrians, and if there is no separation between these two traffic groups, the solutions that are made to improve bicycle safety will not work. Different urban planners with different professional backgrounds will approach the design based on their professional background (Arafi, 1999), therefore, more cooperation between different professionals is required to contribute to a more heterogenic design that creates a community, proximity and neighborhood for the road users, thus increasing safety. This can also help to reach the national policy of a Zero Vision (Nollvisionen) of accidents with severe injuries at the same time as we contribute to the UN Global Sustainability Goals (Trafikverket, 2017).

5. Results

5.1. Introduction

In this chapter of the report, I am only presenting the results of the empirical analysis of the cause of single bicycle accidents selected in Strada database. My intent with this report was to analyse the causes of single bicycle accidents in the chosen investigated areas that located in the centre of Stockholm. The period of the investigation was set between 2010 and 2016. The categorization of the main cause of bicycle accidents (operation and maintenance, Bicyclists interaction with other road users, road design, bicyclists interaction with bicycle and bicyclists behaviour and condition) are used to answer the cause of single bicycle accidents. The results will then be discussed in chapter 6.

5.2. The cause of single bicycle accidents

When are bicyclists most likely to suffer an accident?

According bicycle accident statistic record from Strada, the occurrence of single bicycle accidents is linked to seasons. As the result indicated that most accidents occurred during late spring, summer and autumn while winters saw less accidents. The correlation between the number of accidents and seasons are also linked to weather condition. Weather conditions during the seasons had an impact on the number of bicyclists and this also affects the number of bicycle accidents. Furthermore, rush hour was also the time when most accidents occurred.

Why does an accident occur and what causes are behind bicycle accidents at a chosen place of investigation?

In *operation and maintenance*, most accidents occurred due to skidding on the road, which was either caused by ice, leaves, gravel or loose objects. Other causes in this category were holes on the bicycle path/ road sections. Bicycle accidents related to *bicyclist interactions with other road users* were mainly caused by giving way for other road users such as pedestrians walking on bicycle paths and parking car that opened the door.

Road design-related accidents were linked to the bicyclists driving on or against a fixed object on the roadway. The sidewalk, curb, refuge and cobblestones were often found in this category as the cause of accidents. Other solid objects that have contributed to accidents were tramways, light poles, tunnels, wells and even traffic light poles. Barriers, concrete jams, car cranes and water wells were other factors that have jeopardized road safety for bicyclists to a lesser extent.

Furthermore, the cause of the accidents in the category *bicyclists interaction with bicycle* was severe as well. Most of the causes were because objects got stuck in the wheels of bicycles. In other cases, the bicycle chain had gone off or stuck, or when the bicyclist got off the bicycle and stuck with the foot on the pedal hit the ground. Bicycle steering and saddle had also been a contributing cause of bicycle accidents. Similar to the category of bicyclists' interaction with bicycle, the category of *bicyclists' behaviour and condition* had causes as well, but these were different. The causes of accidents related to bicyclists' behaviour were due to high speeds or talking on phones. Other causes were having a dog on a leash while bicycling, as well as taking a wrong turn on road. For the conditions, it was alcohol consumption that had the highest number of accidents fallowed by bad balance and lack of attention. Some accidents occurred when the wind made that bicyclists lost balance.

Where are bicyclists most likely to suffer an accident?

According to the heat map, places that were prone to bicycle accidents in the investigated areas were between Slussen and Gamla stan. The heat map also shows that the street Götgatan had more density as well. In general, the heat map shows that the investigated areas had more accidents than other place in Stockholm. In terms of road types where accidents occurred, bicycle paths had the most accidents, except for the category of bicyclist interaction with other road users where most accidents happened on the road section. Other places with high accident rates were road sections and intersections. Least accidents occurred on sidewalks

6. Discussion

From a health, environmental and climate change perspective, bicycling has shown to have more advantages than other means of transport (Björklund et al., 2017). Therefore, more and more people are bicycling today, not just in Sweden, but also in other European countries like Denmark and the Netherlands, and this current trend is predicted to keep on growing (Konglin, 2013). The Swedish government has promoted policies and proposals on national and local levels to make the country bicycle friendly as bicycling also contribute to reaching the UN Global Sustainable Development Goals that the government has signed to implement on the national level (Trafikverket, 2017). Unfortunately, the Swedish Traffic Accident Data Acquisition (Strada) shows that most people who are severely injured in traffic are bicyclists, and that most bicycle accidents occur in urban and metropolitan areas (Stockholm city, 2016: Niska et al., 2013; Trafikverket, 2014a). Another report from Trafikanalys contains statistics from patient records about the number of people treated in more than 24 days in hospitals, where a moving vehicle has been involved, show that since 2008 bicyclists are the largest group regarding the number of injured victims searching for medical care (Saxton, 2010).

This study, that is based on analysis of single bicycle accidents in a chosen investigated area in Stockholm, show that single bicycle accidents was the largest bicycle accidents type (48 %) than other bicycle accidents type (See section 4.4). Niska et al. report (2013a) shows that single bicycle accidents were the largest bicycle single type during in Sweden as well, during 2007-2011. The accidents in the investigate areas has increased with 8 % between 2010 and 2016 while number of bicycling has increased with 4 % during the same period. This indicate that accidents increased faster than the number of bicyclists in the investigated areas.

The main category with largest rates of accidents was operation maintenance, followed by bicyclists interaction with road user, road design, and least accidents had the categories bicyclists interaction with bicycle fallowed by bicyclists behaviour and conditions. When compared to the results of the report written by Niska et al. (2013b) about single bicycle accidents in Sweden, it appears that operation maintenance was also the largest main category fallowed by road design, behaviour and conditions, bicycle interaction with bicycle and bicyclists` interaction with another road users. Although, the difference between This study and reports from Niska et al can be found in the sequence of the main categories. For example, the main category bicyclists interaction with road users had least accidents (11%) in Niska et al. report (See section 2:4) while the same category had the second largest accidents rate in this study with 27 %(See section 4.4.2). This difference indicate that bicycle accidents related to interaction with road users happened more often in the investigate areas than in Sweden overall. An explanation to this could be that people bicycle more in urban areas, which has been shown in a report written by the Swedish transport Admnistration (Trafikverket) about the trend in transport system (Trafikverket, 2014a). Bicycle flow has increased with 4 % (See section 2.2), therefore increased of bicycle accidents (8%) during 2010-2016 might indicate that that the infrastructure in the investigated areas is not adapted to the increased of bicycle flow, Most of the bicyclists (informants) during interview claimed that accessibility was difficult at some places in the investigated area due to the design of the transport system, which caused conflicts with other road users (See section 4.5).

The causes of single bicycle accidents were many and differed between each category (See section 4.4). The cause of accidents in operation maintenance was predominated by skidding, while the category of interaction between road users was mostly, due to swerving for other road users. Accidents related to road design was due to curbs and other solid object and bicycle wheel and brake was the most cause of accidents in the category bicyclists interaction with bicycle. For bicyclist behaviour and condition, high speed and alcohol were the causes of accidents related to this category. Another interesting observation was that the bicycle accidents that occurred during the night were more common in the category of behavior and condition, and many of the victims blamed it on alcohol as the cause of accident. Anyhow, it’s clear that every main category had their own unique attribute as a cause of accident which is why

these different attributes may require different approaches to reduce bicycle accidents in urban areas, especially in the investigated area.

Furthermore, all bicyclists during the interview emphasized their dissatisfaction about the current condition in public spaces regarding safety and accessibility for bicyclists. Too narrow bicycle paths and too many bicycles at some time, as well poor operation and maintenance of the road experienced by informant as risk factor that jeopardized their safety and security. The same causes of bicycle accidents mentioned in Strada event description on the cause of single bicycle accidents, were the same problem that informants faced when bicycling in the investigated areas (See section 4.4& 4-5). This dissatisfaction of how it is to bicycle in Stockholm has been shown on Koglin report about how it is to bicycle in Stockholm compare to Copenhagen; it was clearly that bicyclists in Copenhagen were more satisfied than bicyclists in Stockholm (Koglin, 2013). If this trend continues, a consequence can be that people stop bicycling because of fear of injuring in bicycle accident. This could lead to an increase of motor vehicles and decrease of bicycles in Stockholm. Therefore, I agree with Wärnhjelm (2013) about better infrastructure design to stimulate bicycling, as better design of infrastructure has shown to be beneficial in term of preventing bicycle accidents and stimulate bicycling in Copenhagen (Högström, 2009).

Further, men are more overrepresented in single bicycle accidents in this study (See section 4.4.8), this result has raised question about gender equality in bicycle infrastructure. According to Stockholms trafikkontor (2018) men bicycle more than women and therefore there were more men than women in single bicycle accidents at the investigated areas. Based on this I would suggest an analysis of bicycle infrastructure based on gender equality, Mapping the habits of women could help Stockholm municipality to rebuild safe infrastructure, specially bicycle infrastructure that is adapted to women's travel habits and needs. This would encourage more women to bicycle and contribute to reach the municipality's goal, which is 15 % bicyclists by 2030 during rush hour compare to current 10 % (Firth, 2012). Bicycles as a mean of transport has shown to be beneficial in term of reaching sustainability in transport sector, as its emit less than motor vehicle and are environmental friendly (Björklund et al., 2017). With more bicycles in Stockholm municipality and less motor vehicle, Stockholm municipality can contribute to reach Agenda 2030 (United Nations, 2018). I agree with Arafi (1999) about road users as a heterogenic group with different needs based on age, gender and economic preferences and by building a heterogenic infrastructure can attract other group of people, like women for example and lead increasement of bicyclists in Stockholm as well reduce accidents during rush hour.

During the interviews with the bicyclists, many suggested to rearrange bicycle paths, broaden them and create new bicycle paths as there are more people that are bicycling now. Other suggestion was replacing the curb with lines, use saline salting methods during winter on most of bicycle paths and identify all traffic -hazardous solutions that exist and address them. Other suggestions were physical separations from pedestrians and speed reductions to 30 / km in urban areas, as well as teaching bicyclists to pay more attention in traffic as this would reduce bicycle accidents (See section 4:4). This would reduce accidents in all main categories in the investigated area, especially in the main categories bicyclists interaction with road users and operation maintenance. As mentioned in this chapter, operation maintenance had largest accidents rate and was one of the category with largest number of bicyclists with severely injured that was hospitalized in 24 hours or more, followed by bicyclists interaction with road users, and by broaden bicycle path would facilitate overpassing and reduce bicycle accidents during rush hour. A positive indication is that Stockholm municipality worked already with such kind of projects which many informants had noticed as the pointed out during interview that the conditions for bicyclists in the investigate areas are getting better (See section 4.5), but the municipality efforts is not enough as single bicycle accidents has increased with 8 %. These efforts have been criticized as not enough to meet the growing population and bicyclists (Isaksson, 2012; Linde, 2015). Even though the ambition of Stockholm municipality is to promote bicycling, more resources are needed to rebuild bicycle infrastructure that has capacity to meet the growing population as well bicyclists.

Furthermore, there is more to do to prevent bicycle accidents, not just by improving the transport system for road users, but also by improving the reporting of accidents in STRADA. Strada as a resource has

minor errors like there is missing information about time, month and days when the accidents occurred for some accidents. About 100 single bicycle accidents didn't have event descriptions. Moreover, about 25% of single bicycle accidents had uncertain positions. This information about where accidents occurred is important for the municipality because it will help them to put resources where there are needed to prevent bicycle accidents. However, I don't think these errors have huge effect on this study's credibility. But on the other hand, the measurement station had a lot of missing data which I think may have affected the credibility of the number of bicyclists in the investigate area. These tools are important for the work of safety and accessibility for bicyclists therefore improvement of these, in form of better report to Strada and technical for station measurement that withstanding the weather conditions are needed. Moreover, this study has only analysed a short period of accidents, but I think it has contributed with information about the situation during the chosen period. Therefore, the information here is only for the time that the analysis is intended for.

Quantitative methods and qualitative methods have been inevitable as data required both methods. Quantitative methods can be stiff and not capture emotions in the same way as qualitative have the tendency to be subjective. Subjectivity may be good, but also bad as the information can reflect the informants' subjective values, but in this project, all interviewees had the same experiences and in addition, their story was confirmed by the inventory of certain areas. Interviews were made on the telephone and problems could arise with hearing what the interviewer said, and this led to the loss of certain parts of interviews. About 25 bicyclists participated and the number is significant because in qualitative interviews, it is demanding to process this information**.**

Another critic worth to mention are against the main categories, specially the category bicyclist behaviour and conditions: Bicycle accidents that occurred during the night were more common in the category of behaviour and conditions and many of the victims blamed it on alcohol as the cause of accident. In addition to this, the accidents appeared because of the road design as bicyclists collided with curbs and other solid objects on the road and most of bicyclists could not see these risk factors because it was dark. With that in mind, I wonder if the accidents would have occurred if there were no risk factors on the road, even though the bicyclist was drunk? This makes me criticize and question this main category, as in some accidents it appeared that the accidents should be on road and design than behaviour and conditions. To put the accidents in the right main category can change the responsibility of causes of accidents and help municipality to put resources where it is needed. Nevertheless, I am not trying to fully take away the responsibility of the accidents from bicyclists in the category. I am trying to say that consideration should also be given to the role of road design as the responsibility about traffic safety.

7. Conclusion

The aim of this report was to analyse single bicycle accidents in Stockholm centre. The result show that single bicycle accidents increased with 8% during 2010-2016 at the investigated area while bicycle flow has increased with 4%. Single bicycle accidents are the largest type of all bicycle accidents type. In this report 48 % of bicycle accidents consisted of single bicycle accidents. Similar result has been observed on national level: about 71 % of bicycle accidents was single bicycle accidents during 2007-2011 in Sweden. However, based on this study I can agree with previous researches that Stockholm municipality need to put more investment and resource to increase accessibility and safety for bicyclists in urban areas. Transport systems should be design so that they can adapt to the road users and their needs. A way to succeed with this is by taking into considerations to difference causes of accidents, time of accidents and place where accidents occurred in each categories and approach to them accordingly. Another point that I find important is to encourage gender equality and heterogeneity in general in bicycle infrastructure because road users are a group of people with different needs and preferences. Improvement is needed regarding collection of correct data in different technical tool, that are used in work with bicycling and bicycle accidents (STRADA and Bicycle flow measurement stations). Their credibility is necessary as well.

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10. Appendix

10.1. Appendix 1

Operation and Maintenance	Skidding due to Ice/Snow, gravel, and rain, wind, -Uneven surfaces in the form of pits and cracks; -Loose objects, roadworks and parked cars; -Ended up off the road and lost balance; -High Asphalt edge.
Road design	Driven towards or over the curb or other curb-solid objects such as concrete sows, bars, lamp posts, and trees; -Driven against rails, stuck in/slipped on tram rail tracks.
Bicyclist interaction with bicycle	Stepped off/on the bicycle -Damage on bicycle, chain jumped off, brakes didn't work, etc. -Stuck with something in the bicycle/transported objects; -Halt stop due braking with handbrake and braking in general.
Bicyclists behavior and conditions	Handling errors e.g. bicycling with one hand, or "slant" on the pedal - High speed -Alcohol and suspicion of alcohol after parties; -Distractions i.e. using phones; -Playing while bicycling, including those who transport people -Own dog i.e. the dog stalls or similar and pulls over the bicyclist; -Uphill where dryer ended; -Windy weather that made the bicyclist loose balance. -Dazzled by the sun.
Bicyclist interaction with other road users	-Swerved for other road users - Swerved for dogs, including those on leashes; -Dazzled by Vehicles.
Disease	Fallen due to illness i.e. heart conditions, faints and so on.

10.2. Appendix 2

Interview Guide: Bicyclists ' experiences of bicycling in Stockholm

Dear all,

My name is Cecile and I'm studying the Master's program *Sustainable development* at Uppsala University. Currently, I am writing my thesis on bicycle accidents in Stockholm in collaboration with the Stockholm City traffic office. I would like to get in touch with you for an interview about your experience in bicycling in Stockholm. I would be extremely grateful if you could take the time to be interviewed by mobile phone or answer the questions below and email me at: Cecile.Nseya.4773@student.uu.se by March 5th 2018.

Bicycle accidents is a significant issue in urban areas which is why your views on how it is to bicycle in Stockholm is an important part of the work to improve safety for road users. I am mainly interested in bicyclists who bicycle in these areas in Stockholm: Vasastan, Norrmalm/Östermalm, Kungsholmen, Gamla Stan/Slussen and Medborgarplatsen. Participation in the survey is voluntary. All interview material will be deleted after it has been processed, and no data will be disclosed to anyone. All interviewees' answers and personal information will be kept confidential and will be anonymous. You are also welcoming to take part of the final report by contacting the Stockholm Traffic Office, or read the results at Uppsala University: http://uu.diva-portal.org/smash/search.jsf?dswid=-864

Interview questions are divided into 4 parts: The first part is about bicycling habits; the second part is about the experience of the physical environment and mobility by bicycling in Stockholm; the third part is about your view of what causes bicycle accidents and whether you have been involved in bicycle accidents; and the final part is about your gender and age, including any other information that you would want to disclose. For parts two and three, you can skip the questions if you have not been involved in any bicycle accident between 2010 and 2016.

Part 1: Bicycle habits

1. Where in Stockholm do you usually bicycle?

2. How often do you bicycle and in what context?

3. How do you experience mobility on the roads for bicyclists during the different seasons (summer, autumn, winter, and spring)?

4. During which hours of the day is best and worst to bicycle, and why?

5. *How do you experience the interaction on the roads with other road users (motorists, cyclists and pedestrians)? Please tell us both positive and negative experiences when it comes to the interplay between road users which you have been through or seen on the road.*

6. Why do you travel by bicycle and no other means of transportation such as cars, busses, or walking?

Part 2: Road design and physical environment

1. What do you think of the road design of the GC Circuit/bicycle field in Stockholm in terms of its width and the possibility of getting through without colliding with another road uses?
2. In the case of bicycle paths, what do you think about its topography, i.e. if they are even, have up and down hills, pits, etc.?
3. How do you experience the mobility of bicyclists on the roads, for example at roundabouts and intersections?
4. What is your view on the operation and maintenance of bicycle paths in Stockholm during the different seasons?
5. According to you, what are the most important measures to improve safety for bicyclists?
6. Based on your experience of bicycling in Stockholm, how do you feel that the city of Stockholm is committed to increasing the safety and security of the bicyclists?
7. How do you see the safety and security of bicyclists in Stockholm overall? Can you point out a place from your experience that is not safe to bicycle on and please state why (Niska et al, 2013a)?

Part 3: bicycle accidents

1. What do you think are the main causes of bicycle accidents, especially singles accidents e.g. poor road maintenance, distractions such as mobiles, listening to music, dog in a band,
alcohol effects, high speeds, lack of spaces, a mixture of different road users, and poor regulatory compliance?
2. Feel free to develop your response here. Have you been involved in a bicycle accident between 2010 and 2016? If this is the case, please state the accident, i.e. its time and place, cause, weather conditions, if you were in contact with the police, hospitals or both?
3. What were your protective equipment at the time of the accident, i.e. helmets, knee pads, gloves, clothing and so on (Niska et al, 2013a)?

Part 4: Other questions

1. Your gender and age?

2. Is there anything else that you want to take up on this topic with bicycling and your experience of bicycling in Stockholm (Niska et al, 2013a)?

Thank you for your participation

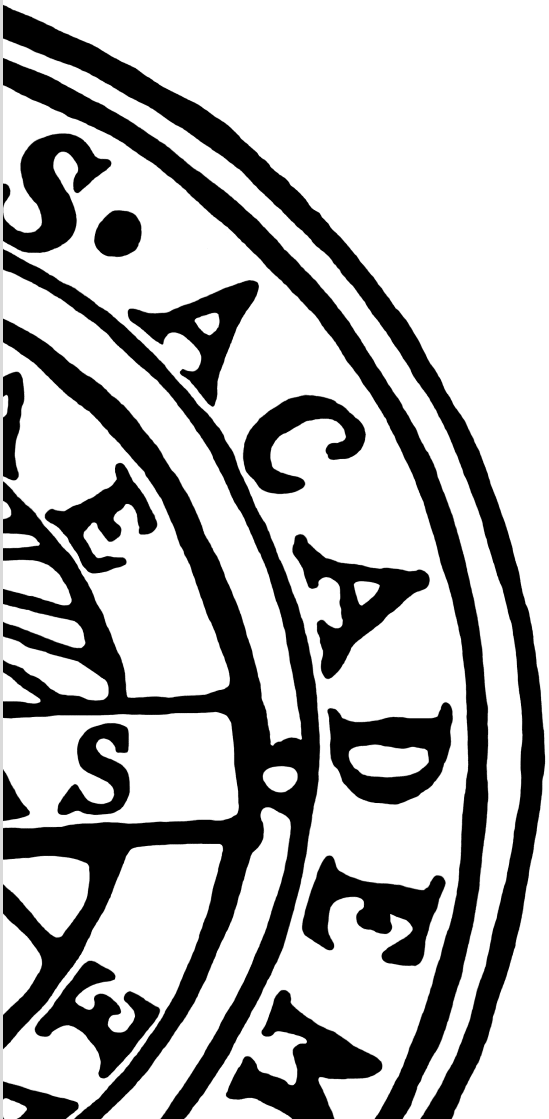
Sincerely, Cecile

10.3. Appendix 3

Emergency Medical Care in Stockholm county

1. Karolinska Universitetssjukhuset Huddinge January 2003
2. Karolinska Universitetssjukhuset Solna September 2006
3. Astrid Lindgrens barnsjukhus September 2006
4. Södersjukhuset September 2008
5. Capio S:t Göran September 2009
6. Danderyds sjukhus October 2010
7. Norrtälje TioHundra Vårdbolag April 2011
8. Södertälje sjukhus April 2011
9. City Akuten Närakuten Children November 2011
10. Lättakuten Danderyds sjukhus February 2014 (stop 1/9 2015)
11. Lättakuten Huddinge sjukhus January 2015
12. Nacka sjukhus January 2015
13. Sachsska barn- och ungdomssjukhuset June 2017
14. Närakuten Haga September 2017

Source: Transportstyrelsen, 2018b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