Bicycle hazards – Do intersections matter?
Acknowledgments

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Abstract

The Swedish city of Umeå is one amongst other cities that has a focus on the increase in the bicycling usage. The municipality of Umeå aims to make public transport, bicycling and walking the most frequently used modes of transport in the city (Umeå kommun, 2017b). There are both positive and negative effects when people are using the bicycle as a mode of transportation. The positive aspects can be increase in health benefits, more environmentally friendly than other transport options and it is a relatively cheap way to transport oneself. The negative aspects can be that more people get hurt due to the risks with bicycling such as physical infrastructure related hazards. The aim of this thesis is to explore if the number of roads in an intersection has any correlation with the amount and severity of accidents and to analyse it in the scope of sustainable development and accessibility. This was done with the quantitative database STRADA which consists of both hospital data and police data on bicycles accidents in the timespan of 2008-2018. The chosen study area was Umeå but with two more specific locations: the city centre and the campus area. Two different approaches were used to utilize the data from STRADA: GIS to create descriptive maps and calculations of the bicycle accidents and logistics-regressions to investigate the accident severity relation to a certain number of chosen variables. The main findings were that it is important that every aspect of bicycling should be as safe as possible otherwise many beneficial effects with bicycling may disappear, such as the ones with sustainable development and accessibility. The results show that there was one type of intersection that had relevance and that was the intersections with three roads in it. Three road intersections were significant in two ways. The first way was that it caused an increased risk in more severe accidents and the second way had an opposite relationship and this was depending on what type of geographical place one was looking at. As with other risk factors there were many variables that affected the outcome of the risk. In Umeå it seemed that people that were over age 39, accidents with vehicles and winter were factors alongside with the three road intersections.

Keywords: Bicycle hazards; intersections; severity; accidents; accessibility; sustainable development;
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1. Introduction and background

1.1 Introduction

Bicycle use has seen a large increase from 1990 up until today. The largest increase can be found in a European context (Pucher & Buehler, 2017). One of the highest share of bicycling trips is found in the Netherlands. Almost 40% of the short trips, under 5 km, in the Netherlands is done by bicycling. Even though Sweden is not on the top of the statistics, they come in at the top three placement alongside Denmark (European commission, 2015). The Swedish city of Umeå is one amongst other cities that has a focus on the increase in the bicycling usage. The municipality of Umeå aims to make public transport, bicycling and walking the most frequently used modes of transport in the city (Umeå kommun, 2017b). In a survey on travel behaviour of the citizens of Umeå that was made by Umeå municipality (2015), shows that 44% of the respondents in the age group 16-84 thought that the bicycle should be prioritized in the planning of infrastructure. In addition the survey showed that 21% of the trips that was done in urban Umeå was made with a bicycle. Umeå is one of the cities in Sweden that has a university and has 31 500 students (Umeå kommun 2017a). This is one of the reasons that the mean age in the city is comparatively low to other Swedish non-university cities (SCB, 2009). Younger people are keener to use the bicycles as their mode of transportation (Rietveld & Daniel, 2004) and this can be one reason why bicycling is rather popular in Umeå. There are other reasons than a younger age which make people to use the bicycle. The reasons can be manifold such as economical, health related ones and ecological. Bicycling in itself has number of benefits for the people that chooses and can use it. It promotes an increase in quality of life but it also contributes to improvement in health such as better overall fitness (Lanzendorf & Busch-Geertsema, 2014). In addition to promotion of the quality of life it is also a transportation mode where the cost of buying and using a bicycle is relatively cheap (Pucher & Buehler, 2017). A third positive aspect may be the ecological one of bicycling, it has a low negative impact on the nature compared to other modes of transportation (ibid). These positive aspects are not the whole story, there are also negative parts as well.

Bicycling as a mode of transport does not come without risks and according to Swedish Civil contingencies agency (MSB) there were 23 000 bicyclists that had to visit the hospital after being in bicycle accidents (MSB, 2009). The increase in bicycling leads to that more people are exposed to risks that comes with bicycling. There is also a socioeconomic cost when people get hurt on different levels, for example the region the person lives in but also for the individual itself (NCO, 2008). This can be viewed for example as the cost of treating the person in the accident which can be the cost for the staff at the hospital. There are many reasons why bicyclists get hurt in accidents. Some of them are related to the physical infrastructure such as elevation and intersections (Teschke et al, 2012). Even though the topic has been researched for over three decades, there is sparse knowledge about bicycle hazards and to what creates these hazards. Intersections are highly related to accidents and the reductions in safety for the bicyclists, but there is still research that has to be done within this area (Reynolds et al, 2009; Moore et al, 2011; Wardlaw, 2014). Reynolds et al (2009) mention that there is a lack of
research on how the numbers of roads in an intersection, which also can be seen as what type of intersection, affects the accident rate and severity of the injury for the bicyclist. Therefore, the type of intersection is an interesting aspect to investigate further in order to contribute to the knowledge base concerning bicycle hazards and may be a way to reduce the negative effects of bicycling.

1.2 Background
The infrastructure in Sweden when counted in real gross domestic product (GDP) has seen an overestimated perception in the total investments due to the usage of nominal GDP (Andersson & Eriksson, 2017). The infrastructure investments in roads and railways in Sweden have seen an overall downfall the last 15-20 years when looking at Sweden’s capital stocks share of GDP. Even though there has been an overall downfall in the investments, the volume of freight and passenger traffic have seen an increase over the course of 20 years (Andersson & Eriksson, 2017; Konjunkturinstitutet, 2012). Notably, there has been an increase in the budget for investments in bicycling infrastructure on a national level in Sweden. The current investments in 2016 was 500 million SEK/year with an increase with 50% for each year under a two year period. The total 2017 budget for infrastructure was 24 billion SEK/year (PROP. 2016/17:1). This showcases that there is a prioritization towards other types of infrastructure rather than bicycling related ones. The government of Sweden has plans to adapt to the increase in bicycling with focus towards more bicycle friendly municipalities. It consists of two assignments: The first one is to come up with a method to measure the number of bicyclists on both local and regional level and to use this as a way to come up with suggestions to adapt to the increase in bicycling. The second assignment is that the Swedish transport administration gets 9 million SEK to share with organizations that gives information and education about safer bicycling, and therefore contributes to a safer environment for bicycling (Regeringskansliet, 2017). The options to promote increased bicycle use are many but the focus has mainly been on policies. Although that is not the only way, there is also a need to implement bicycle infrastructure investments along with strengthening the bicycle culture (Ibid).

Bicycle infrastructure planning is relatively new in a European, Australian and North American context. Up until recent decades it has been neglected and has now been given an increased importance (Pucher & Buehler, 2017) but as a result of this, bicycle infrastructure has fallen behind. It is therefore not being prioritized nor up to date, which is an important factor for the safety of the bicyclists. The development from an unsustainable way of transport to a more sustainable one is preferable. Furthermore, if the aspect of safety is not considered to be high there is a risk that people get hurt on a greater scale. The newly raised focus on bicycle infrastructure may not be a coincidence since the use of bicycles as mode of transportation has seen an increase all over the world (Ibid). When looking at the attributes of bicycle infrastructure and its improvements there are many attributes that could be in focus. One of them is pointed out by Wardlaw (2014) which states that intersections designed in a proper way can contribute to a safer environment for bicyclists, if they are built properly. This leads to the aim and research questions of this thesis.
1.3 Aim and purpose
The aim with this study is to investigate if the number of roads in an intersection is correlated with the severity and rates of bicycle accidents. By using accessibility and sustainability as analysing tools, this thesis aims at giving a better understanding of what causes the amount of accidents, the severity of these accidents, why they occur and also the implications. This leads to the following research question:

- Where do bicycle accidents in the study area occur?
- Are intersections a greater risk than other types of accident related hazards?
- What variables affects that intersections are more or less of a risk related to bicycling?

1.4 Area description
1.4.1 Umeå
Umeå is a city in northern Sweden and is categorized as a larger city by The Board of Swedish Municipality and County (SKL) division of cities and municipalities. Umeå has a population of 122 892, of which 31 500 are students (Umeå kommun, 2017a). In the scope of this thesis, Umeå can be seen as a city that is based on a west and east divide. The city centre can be seen as part of the west side and the university and hospital on the east side. The city centre is built in a block type of way with streets going north to south and east to west in more or less straight lines. One road that connects these two areas for bicyclists are the bicycle/pedestrian path called Svingen. The university campus and the hospital are on a higher altitude than the city centre which creates slopes from the two areas (See figure 1).
The city of Umeå looks at bicycling as an important part of sustainable mode of transport which in turn can create a more attractive and sustainable city. The municipality of Umeå aims to make public transport, bicycling and walking the most frequently used modes of transport in the city (Umeå kommun, 2017b). Umeå has since 2009 actively worked with creating a main road network for bicycles and has 92% of the main network of bicycle/pedestrians separated from other modes of transportation (Ibid). In Umeå municipality’s deepened comprehensive plan they mention that the bicycle roads should be connected so people feel like it is faster to get from place A to B which creates a greater relative accessibility (Umeå kommun, 2011). They further on mentions that there is a goal of the five kilometre city, this means that built up areas should in the best possible way be built in five kilometres from either city centre or campus area (Ibid).

1.4.2 Transportation in Umeå

It is not only Umeå municipality that prioritizes the bicycle as mode of transportation. In a survey on travel behaviour made by Umeå municipality (2015) where roughly 2800 people living in Umeå between the ages 16-84 participated, 46% of these respondents thought that bicycling as mode of transportation should be prioritized in the traffic planning. The survey further on shows that there is a difference in which mode of transportation that is chosen based on the age of the respondents. 66% of the respondents in the age group of 65-84 chooses the car as their main mode of transport whilst 40% of the respondents in the age
group 19-29 uses the bicycle and 31% of the respondents in the age group of 16-19 chooses public transport. The survey also shows that there is a difference when people are choosing to use their bicycles based on the season of the year (See figure 2). There is a decrease in all of the categories from summer to winter except in rarely/never. 47% of the respondents answered that they took their bicycle daily under the summer season whilst 22% did it under the winter season. This points to that less people are using their bicycles during the winter compared to the summer season.

![Figure 2. A diagram of the difference in bicycling frequency in Umeå 2014 depending on the season of the year. (N)=2684. Source: Umeå kommun (2015)](image)

1.5 Significance of the study and chosen locations

First and foremost, as mentioned in the introduction, there is a lack of research on the subject concerning the effects that the number of roads in an intersection has on both severity and the amount of accidents, this study could therefore be a contribution to the greater picture involving bicycle infrastructure and the risk connected to it. There is a need to fill this gap and as Walker (2011) frames it: “With most aspects of bicycling research, the best we currently have are hints and incomplete stories” (p. 367). The intersection is one of the most dangerous element when it comes to using a bicycle and around 60% of the accidents occurs in this environment (Asgarzadeh et al, 2016). This fills a role in making one element of bicycling safer or at least more understandable.

Umeå as a study area is interesting due to its goals to improve and make bicycling a norm. There are several reasons why Umeå was chosen. One reason is that more people use bicycles in regional cities with 25 000 - 120 000 inhabitants compared to larger cities with over 200 000 inhabitants (Vandenbulcke et al, 2009). The whole of Umeå was not chosen as a study area, but instead two more specific locations in the municipality was due to several reasons. The first area was Umeå city centre and the reason for this is that the physical infrastructure is built in such a way that there are many intersections located in this area, which made it a good location to use for this research. Another reason was that many cities, mostly in the US, are built with the same infrastructure design, which makes the place in a general way comparable.
chosen area was campus. The first reason for this was that campus areas generally act as trip generators (Wang et al, 2012) which means that there are many trips to and from campus. With the 31 500 students that are living in Umeå municipality makes it a reasonable area to study. The second reason is the increased awareness of sustainability that exists in a high degree of students around campuses. The top priorities overall concerning sustainability was several but one of them were sustainable transportations (Yuan & Zuo, 2013). Therefore could the priority on sustainable transportations lead to an increase in share of people that uses bicycles due to their awareness. If one looks at two study areas combined the focus in Umeå municipality’s deepened comprehensive plan has have these as a focus in building newly built-up areas. This means that there are plans to build and reform these two which can lead to a transformation in the physical infrastructure and therefore places that has options in improving the bicycle infrastructure.

2. Theoretical framework and literature overview

This sections purpose is to shed light on what the thesis will be based on both in a theoretical way but also in an empirical way. The theoretical framework will work as a way to frame the thesis and make it possible to discuss from a view that is based on theory. The literature overview will have its purpose in understanding the cause and effect when it comes to mainly infrastructure-based bicycle accident but also other angles on the subject. The start of the chapter will include two main theories: accessibility and sustainable development followed by the literature overview over bicycle hazards.

2.1 The concept of accessibility

Accessibility is not only a concept that is related to place, even though it is inherently. It brings structural conditions such as social issues and poverty in to play as well (Farrington, 2007). The relation to place seems rather obvious but the place also relates to the people living there. This can mean that the people living in certain places do not have access to opportunities, such as infrastructure or certain mode of transportation (Ibid). Accessibility is a normative concept which means that if the people feel like they are in need of a greater accessibility, they will demonstrate for it to be fixed (Ibid).

Accessibility is well known and used in both transportation geography and in policy making (Farrington, 2007). The conception of accessibility can be viewed in different ways and one way can be to divide the conception in its meaning in macro and micro scale. On the macro level it can be defined as the ability for people and business enterprises to access certain activities that is a part of society. The ability to do so can be measured in different ways such as Euclidean distance, the time it takes from A to B and the cost to make the trip, but also the relative measure how safe it feels and the comfortability. In a micro perspective it can be viewed as the individual's ability to move and the actual environment where one can do so. This means that it is necessary to acquire both information of the individuals and knowledge about the environment (Hydén, 2008).
Geurs & van Wee (2004) recognize four components that can be connected to the accessibility definitions and these are: land-use (1), transportation (2), temporal (3), and individual component (4). The land-use component (1) has three dimensions, the quality and amount of certain opportunities that people can use, the demand for accessibility, and the competition of the accessibility. Transportation (2) covers the lack of utility to use certain modes of transport which can be viewed in a time, cost and effort sense. The effort sense includes the relative accident risk and the reliability that is connected to use the accessibility. The temporal (3) component consists of the time that is available to access certain opportunities which can be restricted by what time of day it is or time that is being used for other activities such as work. The individual component (4) reflects the need, the ability, and the opportunity a person has and can result in that certain opportunities connected to the accessibility cannot be used (Geurs & van Wee, 2004). One cannot separate these components due to the interaction and effect they have on each other and in the best of worlds, all these should be considered when using the concept. Even though there are still researchers that approach the concept of accessibility with just one of these concepts and if one does that, it is important to understand which part of accessibility that is included and what the results means. (Ibid).

2.2 Sustainable development (SD)

The concept of sustainability took form in the report from world commission on environment and development: Our common future (1987). The phrase that rang out through the report was: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (p. 41) but the concept has strayed further and been scrutinized from inside and out. Even though the scrutinization of the concept, this is still the most commonly used for sustainable development. There is a built-in tension between sustainability and development when reading the definition: the needs of today whilst it should sustain for the future (Fleurbaey et al, 2014). The concept has been used by various major actors such as companies and government and the critique is that it is rather loose in its meaning and easy to use to justify some actions which render the concept meaningless. The other side of the coin is that some argue that this is the strength of the concept, it’s flexibility which can lead as a guideline on what is needed to achieve rather than how to do it (Giddings et al, 2002). Another definition is the one that is based on not only ecological and economic development but also a social dimension which is referred to the three pillars of SD. Some argue that these three can exist in a balance while others suggest that there is a hierarchy where the economy exists in social matrix but can’t function without the ecosphere (Fischer et al, 2007). The division into the three pillars is a way to separate the parts of SD and can justify a focus on one of the pillars more than the others. The main focus usually lies on the economical sustainability, both in companies and in governments, to exemplify this is the focus on growth in GPD which is one of the most common focus to view sustainability (Giddings, et al 2002).

2.3 Sustainable transportations

In a viewpoint of sustainable transportation, that is transportation ways that are sustainable in the three aspects of sustainability, the bicycle is one of the best modes of transportation one can use. The bicycle causes almost no damage to the environment which promotes the ecological
part of sustainability. The great health benefits that comes with physical activity promotes it in a social perspective. The cost of not only the bicycle and the usage of it is rather low, but the public infrastructure costs are low as well. The bicycle can be used to travel not only short trips but also medium trips that can be more difficult to walk which also can contribute to a more sustainable transportation system (Pucher & Buehler, 2017). The benefits of bicycles and bicycle use are many but why does not more people use it? The reasons are multifaceted and one way it can be viewed is in social environment, physical and individual factors. The physical environment factors entail several attributes but one of significance is the physical infrastructure. Infrastructure design such as mixed-use bicycle lanes, which is bicycles and pedestrian on the same road, but also separated bicycle lanes matter. This makes people use their bicycle on a larger scale. People choose to not use their bicycles if the design is flawed and does not meet their criteria. The individual part can be perception of risk that comes with the usage and owning of a bicycle (Handy et al, 2010). The perceived risk of being in an injury that involves bicycles and cars is one of the factors that is rated as a high risk among people who bicycles frequently (Winters et al, 2011). Deterrent of not using the bicycle is the highest when the conditions of the road is not perceived as safe, meaning that if the roads are icy and snowy, most of the people would choose to not use the bicycle as a mode of transportation (Ibid). The actual risk of being in an accident with a car is fairly low compared to the perceived risk. A total of 60 % of the accidents did not occur with motorized vehicle involved. This calls for a change in the attention on bicycle/car related accidents (Schleinitz et al, 2015). The risk of being injured when using bicycle is seven to seventy times greater than using a car depending on in which context this is being viewed (Reynolds et al, 2009).

2.4 Literature overview

Previous literature on bicycle accidents and the connected injury severity is vast. The majority of the articles focuses either on the severity of the accidents or the amount of accidents to get a perception about the risks that are associated with bicycling. The main findings are that intersections are argued to be one of the most dangerous part when bicycling (Wardlaw, 2014; Harris et al, 2013). Previous research on the correlation between accidents and intersections can be concluded as such that intersections is an important variable to investigate. The correlation made/found is that there is an increase of accidents and/or severity in these types of environment. Nevertheless, there is no single variable that explains why intersections are less safe but several variables have been used in order to prove this correlation. The focus on which variable that best explain this varies thus providing insight on this problem, but one variable that is found in many studies is the design of the intersection, such as which type of route that is connected to an intersection (Harris et al, 2013; Rivara et al, 2015; Asgarzadeh et al, 2016) and the angle one is being hit in an intersection (Wang & Nihan, 2004; Moore et al, 2011; Harris et al, 2013). The effects of different routes vary which leads to the conclusion that bicycle routes are less safe when entering an intersection (Rivara et al, 2015) whereas another article concludes the opposite (Harris et al, 2013).

Furthermore, previous research show that there is a correlation between speed and the severity of the injury, the higher the speed of the accident, the higher the risk of an increased severity (Harris et al, 2013; Moore et al, 2011; Klop & Khattak, 1999; De geus et al, 2012) and this is
not connected only to intersections but also to non-intersections. There are other variables that correlate with not just intersections but also to biking in a general sense such as the route where the focus has been on infrastructure and how they are designed and used, and the majority of the articles conclude that bicycle paths are as safe or safer than riding on the road with cars (Teschke et al, 2012; Lusk et al, 2011).

Another major difference in the literature is the focus on which type of vehicles that are involved in an accident. The main focus of articles is on bicycle accidents that occur with motor vehicles (MVS) (Wang & Nihan, 2004; De Geus et al, 2012; Schepers et al, 2011; Asgarzadeh et al, 2016). And on the other side, which is not as prioritized, single accidents (Schleinitz et al, 2015; Schepers et al, 2014) and this can be because of the increase in severity that is associated with bicycle and motor vehicles (BMV) accidents and that the frequency of accidents is higher when looking at single accidents. One factor that is considered in the literature is the variable of the more cyclists there are, less safe it is. The theory states that the bicyclists becomes less aware of the environment around them which in itself is not positive for the reduction of accidents but since the bicyclists are more common leads to that the people in MV are more aware instead (Jacobsen, 2003).

The major priority that has been on BMVS accident is not motivated and more focus should be on single accidents because of the higher frequency of accidents which in turn leads to an economic burden and health issues according to Schleinitz et al. (2015). This leads to a controversy which is more important to study, the severity or the frequency of accidents. Additionally, previous research show that behaviour and characteristics of people using bicycles is a suited variable to investigate when looking at bicycle accidents. The research on helmet use shows that if a person is not wearing a helmet leads to an increase in both fatality risk and to be severely injured (Elvik, 2011; Kaplan et al 2014; Rivara et al, 2015). However, according to Elvik (2011) there can be negative effects when using a helmet such as neck and face injuries that can occur at the same frequency or higher compared to people who are not using helmets. In a demographic point of view of previous research show that gender and age are factors that matter when it comes to both frequency and severity in bicycle accidents. Rodgers (1995) argues that men are more likely to be in a more severe accident. However, he further argued that it is still not clear why that is. In addition to this, Rivara et al. (2015) states that people under adult age and over 40 have an increased risk of being severely injured. Alcohol is another factor that comes in to play and the relation between alcohol and accident rates are increasing (Kaplan et al, 2014). The literature points to that the road conditions can affect the risk of accidents when bicycling (Nyberg et al, 1996; De Geus, 2012). The road conditions can be affected by poor maintenance (ibid), bad road surface and kerbs (Nyberg et al, 1996). Poor maintenance includes snow, ice, gravel and wet leaves (ibid). With this considered, there are thus some gaps in this research field that could be filled. The first one is as mentioned in the introduction: if there is a difference in severity and frequency in relation to the amount of roads in an intersection and secondly, there has not been a study that has accomplished to use all independent variables that are considered as explanatory factors when it comes to frequency and severity of bicycle accidents. However, this could be a result of data problem and time frames.
3. Methods and Data

3.1 Data

The main empirical evidence used for this paper was given out for use by The Swedish transport administration (Trafikverket) which is a state agency that handles matters of infrastructure planning in Sweden. They have a database called Swedish Traffic Accident Data Acquisition (STRADA) and this is the database that was used for this thesis. The police and the health care authorities are gathering the information for this database by registrations of the traffic accidents and injuries on both a national and regional level in Sweden. The agency responsible for the STRADA database is the Swedish board of transportation (Transportstyrelsen, 2018a). The dataset used for this paper contains bicycle accidents in Umeå municipality over a 10-year period of time, 2008-2018. The dataset contains 59 different variables but not all of them were used (see appendix 1 for list of variables). The total number of accidents in the dataset are 3346 where 1146 have occurred in campus area and city centre.

3.1.1 Variable selection and definitions

As a starting point it is important to know how the measurement of accidents will be used for the thesis and two ways were chosen. The first of these is the number of accidents, the second measurement is the severity of the accident. These measurements were selected for two reasons. Firstly, the previous literature on bicycle accidents are frequently using these two measures to access the risk that is related to bicycling, and secondly, the data from STRADA consists of these two types of data.

3.1.1.1 Dependent variable

The number of accidents and severity of accidents need to have a definition and the first one is rather straight forward, the amount of bicycle-related accidents that have occurred during a given period of time. The latter one is being described with the help of Injury severity score (ISS) which is a measure of the effect of the injuries. This ISS-score is based on an Abbreviated injury scale (AIS). The AIS is based on each specific injury the individual has and is graded from 1-6 where each number stands for the possibility for survival after the injury. The ISS-score is then calculated from the three highest AIS-score in each injury-type of the individual which is done by squaring them. The ISS-score is then scaled from 1-75 which result in different categories where ISS 1-3 is counted as a minor accident, 4-8 is counted as a moderate accident and everything from 9 is counted as a severe accident (Transportstyrelsen, 2018c). This classification meant that the dataset ended up with five categories where 0 equals no injury to the persons in the accident, 1 equals minor accidents, 2 equals moderate accidents, 3 equals severe accidents and 4 equals accidents with fatalities. The fatality category was manually written by the people in charge of STRADA in the data set because the ISS-score does not have a number for fatality. A choice had to be made how to group these variables for the regressions. For this paper it ended up in two different categories: the first one was grouped together into No injury and minor accident and the second became moderate/severe/fatal accident. This was done because of the amount of accidents that were in each category. It wouldn’t be suitable to use no injury on its own category since it only had six cases and the same goes for putting moderate/severe/fatal in the same category. Fatal only had one accident and severe 35. It will still be regarded as an odds-ratio of having an increase in accident severity.
The categorization of severity of the accident will function as the dependent variable due to the questions that is asked for the thesis.

### 3.1.1.2 Independent variables

The variable that represents intersections is rather straightforward definition wise. Either the accident was in an intersection or not which makes it easy to make in to a dummy variable where 1 stands for an intersection and 0 for non-intersection. The intersections influence may reach further than just for accidents that were right in the intersection and Asgarzadeh et al (2016) mention that most of the accidents occurred in a 20 metre radius from the centre of the intersection. This is why an assumption of intersection influence and effect on accidents will be used at this range for the thesis.

There are different types of intersections and they can range from three roads that intersect to almost an infinite number. The intersections for the study area ranges from three to five roads. A three road intersection can be either an intersection formed as a T or a Y. The four road intersection are shaped as an X and the five roads or more can be viewed as a spider-intersection. For this thesis there will be a merge of the four road intersections and five road intersections into a category which will be called four roads or more. This was due to that there were only one accident that occurred in a five roads or more intersection and that there was just one of these intersections in the study area (See table 3 & 4).

The variable representing location for the study area was made with dummies. One for the city centre and one for the campus area. The definition of the campus area was based on the definition from the deepened comprehensive plan for the “University City” made by Umeå municipality where they define the area in a context of the future planning of Umeå. The area consists of the campus area and the nearby university hospital (Umeå kommun, 2013).

The city centre was manually defined from all the points of the compass. The northern border of the study area is made up of the train tracks and the southern border is constituted by the river Umeälven. The highway E20 is the western border, and the eastern border is marked by where Svingen reaches street-level. All these borders of the city centre are of a physical nature, making this part of the study area confined by physical attributes. None of these intersection or location variables could be found in the STRADA-dataset and had to be created in a GIS software which will be reviewed in the section 3.2.3.

The variable of which street/route an accident has occurred in got divided in to four categories. The first one was street/road section where mostly motor vehicles drive. The second was roads for bicycles only and roads for both bicycles and pedestrians use (mixed-bicycle lane). The third was roads for only pedestrian. The last one was miscellaneous category which includes bus stops, town squares and “others”. The “others” in the dataset was not explained further. This last category was made because it was difficult to place them in any of the previous categories. These categories were based on that bicycle and bicycle/pedestrian roads are generally safer than bicycling on the road with vehicles because the road with vehicles are more “noisy” which means that there are more things to pay attention to (Lusk et al, 2011; Teschke et al, 2012).
The next variable was what type of accident. There were three different types that were used: single accidents, BMVS and bicycle-bicycle accidents. Single accidents were related to higher frequency of accidents mainly because this was where most of the bicycling was done and the increased severity was related to BMVS-accidents and bicycle-bicycle (Schepers et al, 2014). In a study in northern Sweden, the majority of accidents that had a fatal outcome was BMV-accidents (Björnstig et al, 1993). This meant that the category ended up with three different dummies.

The variable representing the type of weather when the accident occurred was represented by which season. The choice of categorizing the seasons was based on the spatial location of Umeå. Since it is further north than many other places, this leads to longer periods of cold weather and shorter periods of warm weather. The categorization ends up with April – September as summer or warmer periods and October to March as winter or colder periods. STRADA-database consists of information on road conditions but not for all the accidents which made it more difficult to use as a standard and that is why the seasons became a pointer to which kind of road surface (icy or not) it was at the time of the accident. The literature points to that there is an increase in the number of accidents when bicycling when it is snowing due to snowy and/or icy roads (De Geus et al, 2012; Nyberg et al, 1996). In Nyberg et al (1996) they concluded that poor maintenance of the road was the factor that caused most of the accidents. This category was divided into two different dummy variables as well.

Another variable was age. Previous studies show that the age is an independent factor for bicycle accidents. There were two groups that bicycles that had an increased risk of injury and that was people at the age of twelve and younger and the people at the age of 40 and over. The reason why the first group was more likely to be injured was because they do not pay as much attention as the older people and the reason for people of age 40 or older was because they have an increased physical fragility compared to the younger adults which also leads to an increased severity in the accidents (Rivara, 2015). This variable ended up with three different age variables as dummies: the first one of people under the age of 13, the second as 13-39-year-old people and the third one for people over the age of 39.

Another variable was the gender difference which is based on that men are more likely to be in an accident compared to women (Rodgers, 1995). This ended up in two dummies, one for men and one for women. All variables used in the analyses are described briefly in Table 1.
3.1.2 Limitations in the data

The dataset was not perfect and there were restrictions within it. If one look at it in a general sense, there are both external losses and internal losses of the amount of accidents in the data. External losses can be due to that the people in the accident chose to not go to the hospital or call the police. Internal losses can occur because people working in the hospital or at the police station does not report the accidents to the board of transportation. In a more specific sense of the restrictions in the data, under 2013 there was a problem with the IT-system in the police force which led to a decrease in the amount of accidents and this problem was ongoing up until
2014. This can be observed in the data for 2014 where there were around 20 % less traffic accidents than the average from 2011-2013. There were also a new set of laws that were implemented in 2015. These laws made it more difficult to know how the data should be reported and in combination with this there was high amount on workload in the hospitals which lead to a drop of accidents reported in that year. The people in the accidents had to approve the use of the data for the STRADA-database and since not everyone approved, this lead to a loss of the real numbers. There are no statistics on how great the loss was. There are small precentral changes between different years, types of traffic and the age category which one have to be aware of which leads to a not absolute accurate to make an analysis of the data (Transportstyrelsen, 2018b). This causes a flaw in the reliability of the data. One way of looking at the reliability is to understand the stability of the data. The stability means that the same measure should be consistent over time and have the same meaning (Bryman, 2012). This may not be true but on a regional scale the STRADA-data may be more stable (Transportstyrelsen, 2018b). One of the major limitations is that not all of the variables has data on every accidents which makes it not suitable to use for the regressions. This causes some of the interesting variables to fall out. The helmet use which is connected to lower severity of an accident was in the dataset but just for around 2% of the total population. If a person was under the influence of alcohol, which is connected to higher severity was cut out as well due to the lack of information for all of the accidents. Another limitation is that the dataset doesn’t include every variable that could be connected to bicycle accidents so many variables are left out. This can for example be road conditions such as pot holes on the road, if it was a kerb on the road or if it was poor sight for the bicycle user.

3.2 Method

3.2.1 Choice of method

The choice of method is meant to give an understanding of the effects that the number of roads can have in an intersection which furthermore can be viewed as a risk when using a bicycle. A quantitative approach means that one gets a conception of the reality with the use of numerical and measurable data (Bryman, 2012). The quantitative approach was selected due to one of its natures, which is viewing large number of data to get an overview of the accidents in Umeå. This gives both a spatial dimension and a temporal dimension with many different cases which could be used to make a generalized view and see differences amongst the many accidents that have occurred. This is suitable for the type of questions this thesis is trying to answer which involves both spatial attributes “where” but also the number of accidents and the severity of accidents. The risks this thesis is looking at is generally the same for everyone, if an individual falls with his or her bicycle, one gets hurt, and is therefore quantifiable and the amount of accidents with its explaining variables have a large amounts of data which also suits this type of method.

There are mainly four approaches that were used in investigating the risks when using a bicycle, where three of them are more of a quantitative nature and one that is more qualitative. The approaches are as follows: (1) surveys or interviews with cyclists, (2) analysis of accident statistics or in-depth investigations of accidents, (3) hospital data, and (4) local observations (Schleinitz et al, 2015). These four have different strengths and weaknesses. The two that has
been chosen is the second and third one, which suits the questions this thesis is trying to answer. This is because of the nature of these types of statistics which are based on numbers and the same argument goes for the hospital data. These two different approaches can complement each other in the way that accidents that are not severe enough to be reported by the police can be found in hospital data, the details about the severity and what type of injuries are of more detail. There is a possibility to be more detailed information about the place of the accident in the report from the police since they were on scene where the accident occurred and examples of that can be the type of infrastructure, the environment and driver characteristics (ibid). This is where the data set STRADA has its strengths.

3.2.2 Quantitative methods
The usage of quantitative methods ended up in different types: Making maps and calculations in the software ArcMap which is a way of using geographical information system (GIS) and making regressions with the software STATA. In the next section there will be some explanation about how they were used and how they worked.

3.2.3 Geographical information system
The first one was the usage of GIS in the form of the software ArcMap which have its strengths in being easy for the reader to get an overview of where the accidents have occurred and give a reflection of reality through the creation of maps (Harrie, 2013). GIS was used both as a tool to make calculations that was necessary to analyse the hazards when looking at bicycling but it was also used to make descriptive maps. Descriptive statistics and maps has its strength in making a large population of data to be easier to understand (ibid). When looking at the descriptive statistics such as the maps the first way of categorization of accident severity was used. That is the five different severity categories mentioned in section 3.1.1. No injury, minor accident, moderate accident, severe accident and fatal accident.

To start making the maps several shape files were downloaded from SLU or handed out by Umeå University. These consisted of municipality divisions, where Umeå was one of them, land-use information, bicycle roads and roads for the whole municipality of Umeå and water information in Umeå. These were used for all the maps that were created. The STRADA-database consisted of X and Y SWEREF99 TM-coordinates for every accident which made it possible to plot them on the map. When this was done all of the variables from the STRADA-dataset was connected to each individual point with the help of a unique accident-ID.

In order to create the dummy variables the city centre and campus, polygons had to be made. This was done by creating new polygons and drawing them manually. When doing so, the previous definitions was the guide on how to make them. The creation of the dummies for intersection was made in the following way: The first step was to insert both the shape file for the roads and the shape file for the bicycle roads. The road network was flawed in its setup where several of what looked like straight roads contained two intersecting ones. This had to be fixed so the roads were counted as one whole road and this was done by dissolving the shape file. To make the dissolved road shape file to be a whole system the tool planarize was used with feature to lines. Now the roads were correct in an intersection view. To count the number of roads in an intersection the tool spatial join was used with points intersecting to lines. This resulted in points in every intersection with information on how many roads that intersects at
any given point and these points got a buffer zone for 20 meters which caused a problem. Several of the accidents had occurred in more than one intersection and for these accidents a choice was made. The choice was to connect the accidents to the nearest intersection in Euclidean distance and this was calculated with the ruler-tool from the accidents to the nearest intersection.

3.2.4 Logistic regression

Logistic regression is a statistical method to analyse the odds of something will happen or not happen. It is explained with the help of independent variables effect on a dependent variable. The dependent variable can be set up in different way. One way is that the dependent variable has two outcomes such as pass/fail and is then a binary variable thus the model is a binomial regression. Another way is that the dependent variable is a categorical one either with an order or not an order. If it is order then an ordinal logistic regression is the most suitable. If it is not ordered then a multinomial logistic regression is suitable. The model chosen for this thesis is of the binary nature. The outcome will either be a moderate/severe/fatal accident or not. The formula for this can be expressed like \[
\log \left( \frac{p}{1-p} \right) = a + b_1 x_1 + \ldots + b_k x_k
\]
where \(a\) and \(b\) are parameters and the function of \(p\) is the log odds (Nationalencyklopedin, 2018).

The main reason the logistic regression was chosen was because of the questions this thesis is trying to answer. The view of risk that something occurs is connected to odds of something happening or not. If one was to choose another method, such as an OLS, then the results would somewhat be problematic to interpret because of the linear probability relationship. This means that risk can’t be in focus. Another reason why logistic regression was chosen rather than an OLS is that the OLS is more suited for a continuous dependent variable which is not the case in the STRADA-dataset and this will most likely have some interpretation and estimation flaws due to the low amounts of possible outcomes. One of the other methods that was considered was the Poisson regression. Poisson regression is advantageously used as it can fit lower means, despite of them being skewed. However, as the dependent variable (severity of accidents) in this analysis was more suitable as a binary outcome variable rather than a count variable, a logistic regression model was deemed to be more appropriate since the Poisson is most suitable for count variables.

The logistic regression models for this paper uses only dummy variables for the independent variables and this has pros and cons. It creates a high degree of flexibility when making regression models (Garavaglia, 1994). The downside of it all is that it requires a lot of work and thinking before making them (ibid). In some cases it is pretty clear such as gender: either you have the gender man or woman, but in other cases it may require more thinking. There are examples of these types of dummies for this paper. The season dummy had to be thought through due to the difference in weather from season to season. This could influence that some accidents have had colder weather even though they end up in the category of “summer”.

Certain variables were chosen and others were not and there was a reason for that. The reason is that some variables are more difficult to use and count. For this dataset, there were many variables that existed but did not have enough coverage over the dataset and this in itself is of course a weakness, but even though there are white noises it is still preferable to use an logistic regression that shows something that is rather accurate than not accurate at all.
The logistic regression was made in STATA to create three different models. The three models will be referred to by different names in the regressions. The first model is called ‘Intersection’, the second model ‘Roads in intersection’ and the third model ‘Roads in intersection + spatial attributes differences’. All of the models had the same dependent variable which was binary and included three different accident severities. The severities were moderate, severe and fatal and was coded as 1 whilst the other severities no injury and minor accident was coded as 0. This meant that the models showed the odds ratio for being in a moderate/severe/fatal accident which in the regressions will be referred to as an accident with higher severity. This was because it is a higher severity than the no injury and minor accidents. All the independent variables for all three models were dummy variables which meant that for each dummy variable, there must be a reference variable, which also is a dummy. To see the reference for all dummy variables that was included throughout the models see table 2. The three models had almost every independent variable in common, the only difference between the ‘Intersection’ model and the ‘Roads in intersection’ model was the change of intersection to what type of intersection. This meant that in the ‘Intersection’ model intersections in general was included and that is accidents that have occurred within a 20 meter radius from an intersection. While the ‘Roads in intersection’ model focused on what type of intersection which therefore lead to the inclusion of accidents in three road and four or more roads intersections instead of intersections in general. An inclusion of interaction variables were used in the ‘Roads in intersection + spatial attributes differences’ model. This basically meant that one takes the ‘Road in intersection’ model and use an interaction on the independent variables. The interaction chosen for this model was with campus. This meant that one could see the difference between campus (interaction effect) compared to the city centre (main effect). To understand the outputs this creates one should do robustness tests. First test was to see if the second and third model fitted together and this was done with a likelihood-test which got a p-value of 0.01. The second test was to see the relationship between the main and interaction effects which was done with a margins plot for all the variables. To summarize this, the first model included intersection and additional independent variables, the second model included three road intersections, four road or more intersections and the same additional independent variables, the third model included the same independent variables as the second model but in addition an interaction term was introduced between all independent variables and campus.
Table 2. Dummy variables and the following reference variables.

<table>
<thead>
<tr>
<th>Dummy in model</th>
<th>Reference variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection</td>
<td>Non-intersection</td>
</tr>
<tr>
<td>Three road intersection</td>
<td>Non-intersection</td>
</tr>
<tr>
<td>Four road intersection</td>
<td>Non-intersection</td>
</tr>
<tr>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>Campus</td>
<td>Centre</td>
</tr>
<tr>
<td>People under age 13</td>
<td>Between 13-39 in age</td>
</tr>
<tr>
<td>People over age 39</td>
<td>Between 13-39 in age</td>
</tr>
<tr>
<td>Bicycle-bicycle</td>
<td>Single</td>
</tr>
<tr>
<td>Motorvehicle - bicycle</td>
<td>Single</td>
</tr>
<tr>
<td>Road</td>
<td>Bicycle and bicycle/pedestrian road</td>
</tr>
<tr>
<td>Pedestrian road</td>
<td>Bicycle and bicycle/pedestrian road</td>
</tr>
<tr>
<td>Misc place category</td>
<td>Bicycle and bicycle/pedestrian road</td>
</tr>
<tr>
<td>Winter</td>
<td>Summer</td>
</tr>
</tbody>
</table>

3.3 Method discussion

3.3.1 Ethical considerations

To start of the discussion, it is important to take action so that individual’s privacy and integrity will stay intact. The data in this thesis represents individuals in reality, which makes it important from an ethical and moral view to not list out something that could enable to identify them specifically. This was done by not showing the variables of each specific individual together, i.e. gender, age etc., and aggregating the results.

3.3.2 General discussion and critiques

The quantitative method has not been used without getting criticism throughout history. One of the larger critiques is that the method doesn’t give a perfect view of reality and one of the reasons for this is that individuals are being handled as a number (Bryman, 2012). This causes a problem since for example, all the males do not have the same characteristics and behaviour, and can’t be viewed in the same way since not all males act the same. There is no way around this for this study due to the approach but if one had more in-depth details this maybe could be explored in an alternative way. This problem of behaviour is something that could not be measured in this thesis and one must understand the implications that this is a generalized view of reality and that there will be white noise in the results and calculations. Even though this is one side of the coin, the other side can be viewed differently. If one would explore the individuals characteristics with a qualitative method several things would change. Firstly, it would not be as objective as a quantitative method since the influence of the people could have many different outcomes, and secondly the results would be difficult to apply for the whole population of people (Libarkin & Kurdziel, 2002) that have been in bicycle accidents. And by using data and statistics, the personal beliefs can be said to have less of an impact on the results (ibid).
The categorization of the accident severities can be viewed as a critique in general. The choice to group the categories where moderate, severe and fatal are treated the same may be misleading. Of course a fatal accident is worse than being moderately injured but due to the lack of data in each category I found that this was still the right way to go. The results still shows the difference from a minor injury and no injury compared to being moderate, severe and fatal and is a relative way of looking at an increased risk of being more severely injured.

Other critiques of the method were found with the usage of GIS. The roads that appeared to be intersected on the map was not in reality. The reason for this was that it could be a road that crossed over or under another road which makes an intersection that doesn’t exist in reality. This was dealt with by removing the ones that was not correct with the help of a satellite map that made it possible to extinguish all of the false intersections to my knowledge, but some were more difficult to identify and therefore there may be few intersections that do not exist in reality in the data. The second critique is that the shape file for the roads was not perfectly made. The impact of the roads being laid out wrong with just a pixel in the wrong direction caused that roads where intersecting in the map but not in reality. This was fixed manually but as mentioned before, it was difficult to pinpoint every location where this could be a problem so there may be a few intersections that does not exists in reality. One thing that one must be aware of is the modifiable areal unit problem (MAUP). This means that when one is aggregating the data to different zones and/or scales the result won’t be the same (ESRI, 2018). The range of the city centre was made based on a motivation but if a choice would have been to include for example Svingen in the chosen area, the results would maybe become different. Therefore it is important that one understand the results based on the choices one have made with the scale.
4. Results
4.1 All accidents

Table 3. Table of the amount of certain types of intersections. Source: Data provided by SLU

<table>
<thead>
<tr>
<th>Amount of roads</th>
<th>Campus</th>
<th>City centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three</td>
<td>221 (61,6%)</td>
<td>184 (40%)</td>
</tr>
<tr>
<td>Four</td>
<td>137 (38,2%)</td>
<td>276 (60%)</td>
</tr>
<tr>
<td>Five</td>
<td>1 (0,2%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Total</td>
<td>359</td>
<td>460</td>
</tr>
</tbody>
</table>

Table 3 shows the amount of certain type of intersections in both campus and in the city centre. The two differ from each other where campus has a majority of three road intersections and the city centre has a majority of four road intersections. The percentage division is almost mirrored for the two areas where campus has 60% three road intersections and the city centre 61,6% four road intersections. The total amount of intersections is slightly different where there are 359 intersections in campus but 460 in city centre.
Table 4 shows the amount of accidents related to accident severity for the chosen variables. The colour scheme is showing a group division where it goes from white for one group to grey for next group which means that every time the colour changes there is a new group. The accident severity scale has a pattern where the highest share of accidents is minor and reduces for every jump in the scale. 53,7% of the accidents have occurred in intersections which sums up to 616 accidents. When looking further in to intersections one can see that most of the accidents have occurred in intersections that have four roads connected to it with 57,3% and three road intersections have had 42,5% of the accidents while there is just one that has occurred in a five road one. When looking at the two study areas: campus and city centre there is a majority of accidents in the city centre with 58,6% of all accidents. Which type of road or infrastructure an accident has occurred in has its majority in bicycle and bicycle/pedestrian roads with 54,1% and the second most on roads with 37%. Almost three fourths of the accidents have occurred as single accidents. Summer season has a majority of accidents with 63,4 %. Most of the accidents according to the age groups have been between 13-39 years old with almost 60% whilst people over age 40 have been in 38,2% of the accidents and 2,7% for people under 13 years old. The share between women and men is rather equal with 55,6% of the accidents are women and 44,4% are men.

<table>
<thead>
<tr>
<th>Variables</th>
<th>No injury</th>
<th>Minor</th>
<th>Moderate</th>
<th>Severe</th>
<th>Fatal</th>
<th>Total accidents</th>
<th>Total accidents (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection</td>
<td>4</td>
<td>434</td>
<td>158</td>
<td>20</td>
<td>0</td>
<td>616</td>
<td>53,7</td>
</tr>
<tr>
<td>Non-intersection</td>
<td>2</td>
<td>378</td>
<td>134</td>
<td>15</td>
<td>1</td>
<td>530</td>
<td>46,3</td>
</tr>
<tr>
<td>Three roads</td>
<td>3</td>
<td>188</td>
<td>63</td>
<td>8</td>
<td>0</td>
<td>262</td>
<td>42,5</td>
</tr>
<tr>
<td>Four roads</td>
<td>1</td>
<td>245</td>
<td>95</td>
<td>12</td>
<td>0</td>
<td>353</td>
<td>57,3</td>
</tr>
<tr>
<td>Five roads</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0,2</td>
</tr>
<tr>
<td>City centre</td>
<td>4</td>
<td>469</td>
<td>174</td>
<td>24</td>
<td>1</td>
<td>672</td>
<td>58,6</td>
</tr>
<tr>
<td>Campus area</td>
<td>2</td>
<td>343</td>
<td>118</td>
<td>11</td>
<td>0</td>
<td>474</td>
<td>41,4</td>
</tr>
<tr>
<td>Road</td>
<td>3</td>
<td>299</td>
<td>110</td>
<td>12</td>
<td>0</td>
<td>424</td>
<td>37</td>
</tr>
<tr>
<td>Bicycle and bicycle/pedestrian road</td>
<td>2</td>
<td>440</td>
<td>159</td>
<td>19</td>
<td>0</td>
<td>620</td>
<td>54,1</td>
</tr>
<tr>
<td>Pedestrian road</td>
<td>1</td>
<td>46</td>
<td>21</td>
<td>2</td>
<td>0</td>
<td>70</td>
<td>6,1</td>
</tr>
<tr>
<td>Miscellaneous infrastructure</td>
<td>0</td>
<td>27</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>32</td>
<td>2,8</td>
</tr>
<tr>
<td>Single accident</td>
<td>6</td>
<td>581</td>
<td>241</td>
<td>28</td>
<td>0</td>
<td>856</td>
<td>74,7</td>
</tr>
<tr>
<td>Bicycle-bicycle accident</td>
<td>0</td>
<td>89</td>
<td>28</td>
<td>2</td>
<td>0</td>
<td>119</td>
<td>10,5</td>
</tr>
<tr>
<td>Vehicle accident</td>
<td>0</td>
<td>143</td>
<td>22</td>
<td>5</td>
<td>0</td>
<td>170</td>
<td>14,8</td>
</tr>
<tr>
<td>Summer</td>
<td>4</td>
<td>530</td>
<td>168</td>
<td>24</td>
<td>1</td>
<td>727</td>
<td>63,4</td>
</tr>
<tr>
<td>Winter</td>
<td>2</td>
<td>282</td>
<td>124</td>
<td>11</td>
<td>0</td>
<td>419</td>
<td>36,6</td>
</tr>
<tr>
<td>Age 13&lt; years</td>
<td>0</td>
<td>21</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>2,7</td>
</tr>
<tr>
<td>Age 13-39 years</td>
<td>3</td>
<td>497</td>
<td>150</td>
<td>8</td>
<td>0</td>
<td>658</td>
<td>59,1</td>
</tr>
<tr>
<td>Age 40&gt; years</td>
<td>3</td>
<td>268</td>
<td>128</td>
<td>26</td>
<td>1</td>
<td>426</td>
<td>38,2</td>
</tr>
<tr>
<td>Men</td>
<td>4</td>
<td>346</td>
<td>127</td>
<td>22</td>
<td>8</td>
<td>499</td>
<td>44,4</td>
</tr>
<tr>
<td>Women</td>
<td>2</td>
<td>348</td>
<td>162</td>
<td>13</td>
<td>1</td>
<td>626</td>
<td>55,6</td>
</tr>
</tbody>
</table>
4.2 Intersection accidents

Accidents with severity related to intersections in campus area in Umeå 2008-2018

Figure 3 illustrates a map where the bicycle accidents have occurred between 2008-2018 in the campus area in Umeå. The accidents have been graded in how severe they have been but also a divide if it took place in an intersection or not. The grade is based on a colour scheme where green symbolizes a minor accident, yellow moderate accident, red severe accident and the light blue when there was no injury to the person. The accidents that occurred in intersections are illustrated with circles and the triangles illustrates the accidents in non-intersections. The amount of accidents that have occurred in an intersection are 226, which is a majority of the
total, and 155 of these are minor accidents. The moderate accidents came up to a total of 64, there are 6 severe accidents and there is also one accident that didn’t involve any injury to the person. The accidents in non-intersections are more with a total of 249 and the majority of these were also here minor accidents with a total of 188. The moderate accidents accounts for 54, the severe for 6 and one accident that didn’t involve any injury to the person.

There is a concentration of spots of accidents which generally can be found in the outer skirts of the campus area. The first one is in the north part on the bicycle road that is going from north-east to south-west. The majority of accidents there are minor and in intersections but there is one severe accident that has occurred in a non-intersection together with a few moderate ones (see circle nr. 1). The second concentration can be found in the south part where the bicycle road goes from south to north. The majority of the accidents there are minor in intersections together with a few minor in non-intersections. One severe accident in a non-intersection and one moderate in an intersection can also be found (see circle nr. 2). To the west of the bicycle road, on the road for motorised vehicles, is a concentration of minor and moderate accidents, as well as a severe accident. The third concentration can be found in the west corner in the south on the bicycle road where most of them has occurred in non-intersections with a mix of minor, moderate and severe accidents. Just north of this is a concentration of intersection accidents where it is a mix of moderate and minor accidents (see circle nr. 3).
Figure 4 illustrates a map where the bicycle accidents that have occurred between 2008-2018 in the city centre of Umeå. The accidents have been graded in how severe they have been but also a divide if it took place in an intersection or not. The grade and the divide is the same as in figure 5.2 and in addition there is a grey colour which symbolizes accidents with fatal outcome. The amount of accidents that have occurred in intersections are 395, of which the majority are minor accidents with a total of 282 accidents. The moderate accidents count up to 96, the severe to 14 and three accidents that had no injury involved. The amounts of accidents in non-intersections are fewer than the ones in intersections. The total of accidents in non-intersections counts up to 282 where the majority also here are minor with 190 accidents. The moderate accidents are 80, the severe 10, one fatal accident and one with no injury.
The concentrations of accidents in a general sense can be found in the middle part of the centre where it is sparser to the west and east part. There is also a high concentration of accidents at the bicycle paths that lead over the water. The west bicycle path that leads over the water has both intersection and non-intersection accidents where there are a mix of moderate and minor accidents (see circle nr. 1). The east bicycle path over the water has more intersection-related accidents than non-intersection ones with a majority of minor accidents but also a severe accident (see circle nr. 2).

4.3 Accidents depending on the type of intersection

Figure 5 illustrates a map where bicycle accidents have occurred in an intersection and the number of roads in the accidents intersections on campus area. The number of roads is...
illustrated with a colour scheme where red symbolizes an intersection accident with three roads, the blue colour symbolizes four roads and the green colour symbolizes five roads. The total of all accidents in intersections add up to 226 and the majority of accidents have occurred with three road intersections with a total of 133 accidents. The accidents involving four road intersections adds up to a total of 92 and there is also one accident that has occurred in a five road intersection. The single accident in the five road intersection can be found in the south part of campus where it is in a close proximity of two accidents in a three road intersection. There are no clear concentrations of accidents in a certain type of intersection.
Figure 6 illustrates a map with the same properties as figure 4 but in the city centre of Umeå. The total amount of intersection accidents is 395. There are no accidents that have occurred in an intersection with five roads, but the majority of accidents here have occurred in intersections with four roads. They add up to a total of 265 accidents whereas the accidents in three road intersections add up to a total of 130.
<table>
<thead>
<tr>
<th></th>
<th>Intersection in general</th>
<th>Roads in intersection</th>
<th>Roads in intersection + spatial attributes differences</th>
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<tr>
<td>Intersection</td>
<td>1.106364 (0.73)</td>
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<td></td>
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<tr>
<td>Three road intersection</td>
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<td>.935095 (-.39)</td>
<td>.4852571** (-2.73)</td>
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<td>Four or more road intersection</td>
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<td>1.269494 [1.47]</td>
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<td>1.02197 (0.14)</td>
<td>1.02197 (0.14)</td>
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<tr>
<td>Winter</td>
<td>1.346055** (2.11)</td>
<td>1.35739** (2.17)</td>
<td>1.559708** (2.35)</td>
</tr>
<tr>
<td>Under age 13</td>
<td>1.410242 (0.83)</td>
<td>1.446495 (0.89)</td>
<td>3.235244** (2.35)</td>
</tr>
<tr>
<td>Over age 39</td>
<td>2.145268*** (4.01)</td>
<td>2.15703*** (4.11)</td>
<td>2.455501*** (3.80)</td>
</tr>
<tr>
<td>Men</td>
<td>1.096102 (0.68)</td>
<td>1.100048 (0.71)</td>
<td>1.126714 (0.67)</td>
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<tr>
<td>Bicycle-Bicycle</td>
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<td>.7844753 (-1.05)</td>
<td>.7547423 (-0.88)</td>
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<tr>
<td>Motorvehicle</td>
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<td>.363087*** (-4.20)</td>
<td>.3645579*** (-3.47)</td>
</tr>
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<td>Road</td>
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<td>1.154877 (0.96)</td>
<td>1.349651 (1.48)</td>
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<tr>
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<td>1.142558 (0.47)</td>
<td>1.076354 (0.23)</td>
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<td>.469852 (-1.52)</td>
<td>.4924539 (-1.32)</td>
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<td></td>
<td>3.20751*** (3.21)</td>
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<tr>
<td>Four road or more intersection#Campus</td>
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<td>1.364188 (0.88)</td>
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<td></td>
<td>.7417184 (-1.03)</td>
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<tr>
<td>Under age 13#Campus</td>
<td>.0992579* (-1.97)</td>
<td></td>
<td></td>
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<tr>
<td>Over age 39#Campus</td>
<td>.4170422* (-1.96)</td>
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<td></td>
</tr>
<tr>
<td>Men#Campus</td>
<td>.9832525 (-0.06)</td>
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<td></td>
</tr>
<tr>
<td>Bicycle-Bicycle#Campus</td>
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<td>1.074414 (0.15)</td>
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<td>1.141413 (0.24)</td>
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<td>1146</td>
<td>1139</td>
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</table>

z statistics in parentheses
* p<0.05  ** p<0.01  *** p<0.001

Table 5. Table of the results from three different logistic regression models connected to moderate/severe and fatal accidents and other variables. Source: Data provided by the Swedish transportation administration.
4.4 Regression models for intersections

Table 5 illustrates three different logistic regression models with different variables where all have severity of the accident as the dependent variable. The dependent variable is categorized to show the odds-ratio for being in a moderate, severe or fatal accident.

To start off with the ‘Intersection’ model, intersection and the other explaining variables were incorporated and there were three variables that was significant and these were winter, age over 39 and motor vehicle. The odds-ratio at roughly 1,35 for winter shows that there is an increased risk of being in an accident with moderate, severe or fatal outcome if one bicycles in the winter compared to the summer. The odds-ratio for people aged over 39 yielded out at roughly 2,15 which shows that people in this category have an increased risk of being in an accident of more severe character compared to the people between age 13 and 39. The odds-ratio at roughly 0.365 for motor vehicle shows the opposite relation compared to the previous two variables. This means that there is a lower risk of being in a more severe accident compared to being in a single related accident.

Intersection in the ‘Intersection’ model was not significant. This lead to a decision to take a closer look at different types of intersections. The different types of intersections that was incorporated as independent variables in the ‘Roads in intersection’ model was three road intersections and four or more road intersections.

The ‘Roads in intersection’ model still had winter, people over age 39 and motor vehicles/bicycle accidents as significant with odds-ratios that pointed to roughly the same risk of being or not being in a more severe accident. There was no significance on three road intersections nor four road or more intersections and this was compared to the reference variable of non-intersections. This lead to the next model, ‘Roads in intersection + spatial attributes differences’ model, where a specific location was looked at which was campus. To see if there was a difference between the variables on campus compared to city centre an interaction variable was introduced to all independent variables.

By using an interaction to get this spatial divisions the results came up differently and two new significant variables were added in addition to the previous models. There were also a variable that got dismissed in the model due to too few outcomes, this was Misc#Campus. The main effect (the variables that are not interacted with campus) shows the relation between the variables in city centre, and the interaction effect (the variables that have been interacted (#campus)) shows the relation on campus compared to the city centre. The new significant variables were under the age of 13 and three road intersections. The main effect and interaction effect odds-ratios points to that there is a higher risk of an accident with higher severity if one bicycle in a three road intersection on campus rather than in the city centre. It is less of a risk of a more severe accident if you are over 39 or under 13 of age on campus compared to bicycling in the city centre. The effect of BMV:s loses its significance when looking at the campus area but still has the same significance in the city centre. The main effect also shows that it a higher risk to be in a more severe accident when one is bicycling in the winter but has no significance in the campus area. This points to that there are more variables that matter in the city centre environment than on campus and that the effects differ from each other.
5. Concluding discussion

5.1 The location of bicycle accidents
If we start at a higher geographical scale one can see that there is a difference in how many bicycle accidents that occurs in which area. The majority of the accidents have been in the city centre where 672 accidents out of 1146 have occurred. The reason for this may be that more people are bicycling through this area rather than the campus area which in turn exposes more people to the risks that comes with using a bicycle.

On a more local scale one can see that there are accidents in many places, both on campus and in the city centre which is not surprising due to the time span of 10 years. The accidents in intersection also has a spatial division where 58.8% of all of the accidents in city centre were in intersections compared to 47.7% on the campus area. This can be because of the physical infrastructure differs from one and the other where city centre has a greater amount of intersections in total, purely due to its design. The divide of accidents in which type of intersection is differently in city centre compared to campus where the majority of intersection accidents have occurred in three road ones on campus and four road in city centre. This can also be because of the difference in how many intersections that exists in the two different areas which goes hand in hand with the amount of which type of intersection.

When looking at the campus area there are three concentrations where many bicycle accidents have occurred and all of them is located at the outskirts of the area. The three areas have different mixes of severity but with the majority of minor accidents which is not a surprising result since the overall majority of accidents are just minor. In the city centre the pattern look a bit different where areas with many accidents can be found in the centre region and consists of a mix of accident severities. This could point to that there are several areas which have a higher risk to bicycle through.

When it comes to where most of the different type of severity in accidents occurs, it seems to follow a pattern. Most of the accidents are in fact minor and as Schepers (2014) concluded, this could be related to that most of the accidents are single accident which in turn can relate to a lesser degree of accident severity. Campus area has the highest share of minor accidents compared to city centre and if we move on to the second most common, the moderate accidents, one can see that the highest share of these can be found in the city centre. The third most common is the severe accidents and the highest share of them can be found in city centre. This leads to that in an overall view, city centre becomes more dangerous to bicycle in due to the higher share of moderate and severe/fatal accidents.

5.2 Risks related to bicycling in city centre and campus
When it comes to intersections and the risks that comes with it, both Wardlaw (2014) & Harris et al (2013) says yes there is a greater risk, but there are many variables that comes in to play when using a bicycle. Intersections in general is not a greater risk in the study area which is rather surprising in one way since both campus and city centre have so many of them but in
another way not, because if you have so many intersections in an area then the accidents should vary because of the influence from the other variables. If one looks a bit closer on the intersections, the regressions shows that it is in fact a difference in which kind of intersection an accident occurs in. The three road intersections seem to play a key role for this study where it is both more dangerous and less dangerous to bicycle in. In the campus area the three road intersections are more dangerous than bicycling in a non-intersection which is an interesting result. This can lead back to the share amount of these types of intersections in the area, but other reasons can also be plausible, it is hard to say exactly why because of the lack of research on the subject before but one can speculate. It can be that the combination of several variables has influence in just this situation and it may be variables that have not been interacted with three road intersections such as influence of alcohol, speed or bicycle helmet use and etc. In the city centre the three road intersections have the opposite relation and is correlated with less of a risk and the same argument could be used here, the share of exposed risk is less because of a less amount of three roads intersection in the area. The four road or more intersections had no correlation with the increased severity risk in any of the areas which was not expected due to that it should correlate with the previous research where noisier streets creates a less safe environment because there are more streets to be aware of and more things are happening.

When it comes to the other variables that were significant in the models there are only two variables that shines through in all of them with an increase odds-ratio in severity and this is if you are over the age of 39 and winter. The relation between if you are over age of 39 and a higher risk of being in a more severe accident is not very surprising, since as Rivara et al (2015) concluded: these people have an increased physical fragility even though this is probably truer the higher you get in age. This is a variable that is continuous showing an increase in higher severity of accidents. The odds-ratios for winter does not come as a surprise either since there is an added element to the road which is not current in the summer season. The element is snow and/or ice that makes the road more slippery and therefore make it more plausible to be in an accident in this environment which is shown in Nyberg et al (1996).

The more surprising result is that accidents with motor vehicles are less likely to be more severe and is difficult to explain based on the data but one reason could be that it has to do with a spatial context where people in Umeå tend to be more careful on roads and in vehicles which relates to Jacobsen (2003) theory of safety in numbers which states that the people driving motor vehicles are more aware and reacts faster. The theory also mentions that bicyclists becomes less aware which could take out the effect of the more aware drivers in vehicles but maybe this is not the case in Umeå and could be a contributing factor to the relationship with severity. Another plausible option for accidents with motor vehicles to get a negative odds ratio can be that the correlation between this and fatality as mentioned by Björnstig et al (1993). In this study area there was just one fatal accident which leads to that the representation of these kinds of outcomes does not shine through in the regressions.

The total accidents (see Table 4) shows towards that some variables appear as being more dangerous than others. This is true in one sense but on the other hand not. As the survey on travel behavior (Umeå kommun, 2015) shows, there are more people that chooses to not use
their bicycles during winter times. This means that more people are exposed to the risks with bicycling during the summer compared to winter and therefore there would be reasonable to see more accidents during that period of season. As we can see from Nyberg et al (1996) there is an increased risk of being in a bicycle accident during the winter times due to poor road maintenance. With the consideration that people in Umeå are less keen to bicycle during the winter, it can be considered a relatively higher risk to bicycle during winter compared to summer.

5.3 Accessibility and sustainability

It is important to frame the results to get a better view on some of the possible outcomes and effects which will be done in this section with the scope of accessibility and sustainability.

The goal for Umeå municipality is to create the 5-kilometre city as mentioned in section 1.5 with the idea of a city with high accessibility and a city that in theory does not require certain types of transportation modes such as cars. This creates an opportunity for other modes to be more favourable such as bicycling. This goes in line with the increase of bicycling that has occurred in a European context. This rings well with the sustainable development approach where all three pillars of the concept get included, with some more than others. The main focus is the ecological part, and this is favourable for bicycling. As mentioned by Giddings et al (2002) there is often one part that has priority over one and the other, but in this case, it may not be true even though the ecological part has more focus. There are beneficial side effects that could incorporate all three parts if done right.

If we look at the goal with a geographical scale perspective it seems that the focus of the 5-kilometre city is mainly the one of a macro accessibility perspective, as defined by Hydén (2008), where to shrink the city could create lesser Euclidean distance for its citizens, and where more trips could be made possible with bicycles. But the accessibility is not just the Euclidean distance, it could also be in a relative matter. As Geurs & van Wee (2004) state, there are four components to make something accessible. If the safety of three road intersections is viewed as a higher risk at campus then this leads to the second part of accessibility, which is the relative accident risk and reliability, is not fulfilled. This could in theory counteract the ability to make the city more accessible and lead to less favourable environment for bicycling. This is where the micro perspective becomes important to achieve an accessible city. As mentioned by Hydén (2008), the micro perspective of accessibility means the individual’s ability to move and the actual environment to do so. This can be viewed as incorporated with the 5-kilometre city but there is one part that is missing and that is: is the actual environment safe? This further on leads to the part why people don’t use their bicycles which is the risk perception. The perception of risk means that if people don’t feel safe then they will leave their bicycles at home (Handy et al, 2010) so even though the city can be viewed as more accessible there are still parts of the physical infrastructure that can be viewed as a risk and in our case the three road intersections.

The effect of this could take away all the beneficial effects for the sustainable development which is something that is necessary to make the city more attractive. This could further on lead to several negative effects, such as more pollution from other types of transportation modes, less benefits of health and also a higher cost to be able to transport as an individual. These are
benefits that could come with using a bicycle (Pucher & Buehler, 2017) and will echo with its absence.

The two goals of making Umeå to be more attractive with sustainability and accessibility goes hand in hand and it is important that all of the puzzle pieces come together otherwise it will be just a buzz word that is used to “look good”. Umeå is just one case where one can see that sustainability is in focus. The problem here isn’t that there is an increase in bicycling rather the opposite, there are many benefits with bicycling that one should be aware of, which is related to sustainability. Of course there cannot be a fully prioritization of bicycling since not all people can use this type of transport but it is still something that should be seen as something positive. This leads to that one should see the potential in lifting the bicycle as an important sustainable mode of transportation but if one do so, there are problems that must be fixed. One of them is the lack of priority in investments of the bicycle infrastructure which can be viewed in (PROP.2016/17:1) and it becomes more difficult to tackle infrastructure related hazards with bicycling and this will probably be the case in whole of Sweden as well. In Umeå they have come a long way with their prioritization of separating large parts of their bicycle network from other kinds of traffic and lifting the benefits of bicycling but the problem with intersections are still there. By improving the safety of bicycling and all the aspects around it even more such as the risk of bicycling in not only the intersections but also other aspects connected to physical infrastructure, one can then reduce the negative effects such as the socio-economic costs that comes along with bicycling and let all the positive aspects to outweigh the negative more.

5.4 Limitations and future studies

This study has showcased that there is an increased odds-ratio in being in a more severe in bicycle accident coming from the three road intersections but there are several points that has to be made. One is that the influence was based on a 20-metre buffer zone from the intersections centre which maybe can be viewed as a long distance. This calls for another study to see if the impact of both three road and four or more roads intersections may change when looking at this differently. One way to do this could be to divide the influence of the intersections to 5, 10 and 15 meters influence to see if the same results appear. The reasons why the three road intersections at campus is more dangerous than the ones in the city centre would be interesting to research further if one wants to make this more useful in a local context. Another point that could be interesting to investigate is to use this study in another geographical context and look at this study’s result to compare what differs or is the same in the two studies. The study has its weaknesses and could be done differently for future studies. This can be such as the fallout of so many variables in the regression in Umeå which can point to several things that could change the result and one of the reasons may be the definitions of certain variables such as putting bus stops and town squares in to a miscellaneous category. This could be done differently in the next study to be more precise. Another weakness may be the data from STRADA which had its flaws which was described in section 3.1.2 and could be use together with a more in-depth analysis by using for example interviews. By using both the data and interviews maybe one could fill in some of the blanks in the data and acquire more depth in their study. Yet another limitation is the lack of data on how many that bicycles were and when. This lead to that some hazards was seen as more dangerous than it may have been in absolute numbers. To show the relative risk of being in accidents one could have data about
this information which would give a better understanding of the relative risks that exists during some periods of a season and also in certain places.
6. References


http://centaur.reading.ac.uk/38524/


https://link.springer.com/article/10.1007/s11116-010-9269-x


http://injuryprevention.bmj.com/content/injuryprev/19/5/303.full.pdf

22/1-18

http://injuryprevention.bmj.com/content/9/3/205.short

https://trrjournalonline.trb.org/doi/abs/10.3141/1674-11

https://www.konj.se/download/18.2de5c57614f808a95afcd9b7/1446735314131/Nivan-pa-infrastrukturinvesteringarna-i-Sverige.pdf


http://injuryprevention.bmj.com/content/17/2/131.short


https://www.msb.se/RibData/Filer/pdf/24080.pdf

https://www.ne.se/uppslagsverk/encyklopedi/l%C3%A5ng/logistisk-regression

http://journals.sagepub.com/doi/abs/10.1177/140349489602400410
https://www.riksdagen.se/sv/dokument-lagar/dokument/proposition/budgetproposition-2017-
utgiftsomrade-22_H4031d24/html


saker-cykling/


http://injuryprevention.bmj.com/content/21/1/47.full


http://injuryprevention.bmj.com/content/21/e1/e138


Swedish University of Agricultural Sciences (SLU) (n.d) – *Geodata extraction tool* accessed 24/2-18 from https://maps.slu.se/


Umeå kommun (2011). *Fördjupning för Umeå.* Accessed 18/1-18 from http://www.umea.se/download/18.2906939d15f7bd6b2bb14231/1511266062330/4%20F%C3%B6rdjupning%20f%C3%B6r%20Ume%C3%A5%20Rapport%20Utst%C3%A4llning.pdf


### 7. Appendix

#### Appendix 1

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