UNICA Euromaster in Urban Studies 4Cities

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Master Thesis

2013

A recommendation for a bicycle network in Berlin based on the guidelines of Copenhagen

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Submission: September 1st, 2013

Year of defence: 2013

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UNICA EUROMASTER IN URBAN STUDIES

Abstract

The following research investigates the cycling infrastructure in Copenhagen and Berlin within the framework of a comparative case study. After identifying the guidelines of the Copenhagen cycling network, the guidelines are applied to Berlin in order to create a bicycle network recommendation. The research questions are the following:

How would the city of Berlin develop their cycling infrastructure when following the guidelines of the city of Copenhagen? What are the benefits and disadvantages of cycling? What role does cycling play in a European context? Which factors play a role in cycling behavior? What is the current status of these factors in the two case studies? How can the development guidelines of Copenhagen be applied on the case study of Berlin?

The research is both qualitative and quantitative, involving expert interviews and a self-conducted survey with over 400 participants. The final product of the research is a network recommendation for cycling infrastructure in the city of Berlin, comprised of both a more detailed plan for the inner city, and one for the entire city.

Acknowledgments

The idea for the following research derived from my growing interest in urban mobility. After spending my first winter on a bicycle, I believe that bikes have a significant potential in urban areas and I would like to contribute to the discussion on urban cycling.

I would like to thank everyone who in some way or form contributed to making this research possible. I would especially like to thank: My thesis supervisor Fernando Moliní, who guided me through my work and was available at all times, even during holidays for questions and feedback, those participating in my survey and interviews, everyone who contributed to my education and work experience, my parents, without whom I would have not had the opportunity to receive my education, Thomas, for all his time and effort helping me, Gilda and last but not least Mads for the support.

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1 Introduction

The following research is focused on the analysis of cycling infrastructure in the cities of Copenhagen and Berlin. When reading literature, which is aimed at an international overview of cycling in different countries (for instance J. Pucher and R. Buehler (2012a), and European Conference of Ministers of Transport (2004)), Germany and Denmark are often viewed as fairly similar in their cycling development. When taking a closer look at the two case studies, it becomes clear though, that the differences are fairly large and are worth analysing. Copenhagen is generally recognized throughout literature (publications by the Dutch Bicycle council (2006, 2010), publications by the City of Copenhagen (2013d)) as a city, which has developed a well-used and safe infrastructure for cyclists. While there are aspects, which need further development, Copenhagen has one of the highest modal shares of cyclists and is promoting itself more and more as the leading example when it comes to urban cycling.

While there are many aspects, which play a role in how high the modal share of cyclists is, there is a consensus that road infrastructure is one of the main factors (Furth, 2012). The aim of this study is to analyse the approach of the city of Copenhagen towards their cycling road infrastructure and mirror those guidelines on the city of Berlin. Berlin has a bike share of 10%, but the city has the potential to develop a both a higher share of cycling and a safer cycling environment. By mirroring the Copenhagen guidelines of cycling infrastructure, a high quality cycling network is recommended for the city of Berlin.

1.1 Research question

The research is aimed at answering the following question:

- How would the city of Berlin develop their cycling infrastructure when following the guidelines of the city of Copenhagen?

Following sub questions define the structure of the research:

- What are the benefits and disadvantages of cycling?
- What role does cycling play in a European context?
- Which factors play a role in cycling behavior?
- What is the current status of these factors in the two case studies?
- How can the development guidelines of Copenhagen be applied on the case study of Berlin?

1.2 Methodology

The research is an empirical study, analysing two specific case studies and transferring the outcomes of one case study to the other. The systematic literature review throughout the paper is aimed at

answering the research questions posed above. Both qualitative and quantitative research is integrated in the work, in order to provide a thorough answer to the research questions.

A survey was developed and carried out, involving over 400 participants, rating the satisfaction of users with the cycling infrastructure in Berlin. The questions of the survey were developed based on the biannual survey carried out in Copenhagen. The survey could be accessed online and was distributed by groups on social media, who are involved with cycling or have some cycling interests. Since the participants weren't directly addressed there is no response rate. The detailed results of the survey are attached in the Annex (8.1.), while the main findings are integrated throughout the work. Further, professionals, Niels Jensen, working for the traffic department in the Technical- and Environmental Administration of Copenhagen and Martin Schlegel, traffic referent of the BUND Berlin, both involved in planning, provided their opinions in August. The full interviews are attached in the Annex (8.2.).

The paper is structured in four main sections. The first part of the work outlines a basic understanding of cycling, describing the benefits and disadvantages of cycling and the context of cycling in the European Union (chapter 1 and 2). The literature used for this part is mainly peer and non-peer reviewed literature, publications by various EU organizations and statistical databases. The second part defines the factors, which play a role in cycling behaviour (chapter 3). Since the focus of the research is to outline the infrastructure guidelines, some aspects are dealt with in more detail than others. Aspects such as the typology of road infrastructure, safety and land use development are described in detail, since they have a direct effect on road infrastructure, while factors such as weather and social status, while being relevant for cycling behaviour, do not have a direct effect on the road infrastructure. The literature was mainly based on peer and non-peer reviewed literature, online sources and policy publications. The third part of the work applies the case studies to the factors found in the second part (chapter 4), relying on local publications and reports from the two cities. International publications were also used, if they were specifically involved with one of the case studies. The fourth and final part of the paper relies partially on the findings of the previous chapter, while analyzing both data and maps in order to create the final network recommendation (chapter 5 and 6).

Many maps are used in the final analysis, concerning for instance population density, urban centres, public transportation nodes, etc. In the case of cyclist accidents in Berlin, data provided by the police is elaborated, the locations with most accidents identified and then represented in a map. Further, for the final network recommendation many maps are analysed and self-made images and graphs are integrated in the analysis.

The literature used for the entire research is mainly English, but German and Danish sources are also used. APA style referencing was used throughout the text. Over 75 sources are used for the research, while an overwhelming part of them have been published in recent years, the oldest source being from 2004.

1.3 Research constraints

The framework of the research does not allow to thoroughly analyse all factors influencing the cycling share. For this reason specific factors are chosen for thorough analysis, while others are only touched upon. The developed recommendation is a suggestion for the built road infrastructure, while ignoring other relevant factors. This means that the proposal has strong limitations in validity and can be viewed as what the ideal outcome of cycling infrastructure could be, all other factors given. As much as it would have been interesting to develop a cycling plan, integrating all factors of cycling, the current dimensions of the work do not allow for that.

Since the aim of the research is to transfer practices from Copenhagen to Berlin, as given, there is some deficit in the critical view on the Copenhagen model. The aim is not to find the deficiencies in the Copenhagen case studies, but to outline the relevant factors, which lead to a high cyclist share.

1.3.1 Limitations

A restraint, which showed early in the research, is in regard to the qualitative analysis of cycling. Countries and cities use different methods to calculate the cycling share, which makes it difficult to compare numbers directly. The comparison, based on local numbers is still made, but they should be handled with caution due to their constraints.

There are also some constraints due to the language of publications. While Copenhagen is making an effort to make information available in English, some difficulties in retrieving information were encountered, while the documentation of the cycling infrastructure in Berlin is limited, especially in comparison to Copenhagen.

2 The context of cycling

The following chapter is aimed at providing a general context for understanding the role of cycling at a personal, local, national and global level. This is developed in four parts: Outlining the issues of current urban transportation, describing the benefits of cycling, describing the disadvantages of cycling and finally, since both case studies are located in the EU, giving an overview of cycling in the EU.

2.1 Developments in Urban Mobility

There has been an unprecedented urban growth over the last decades, in 2008, for the first time in history there was an even split between the population in rural and urban areas. In the same year there were over 400 cities with a population of over one million and 19 with over 10 million inhabitants (Population Reference Bureau, 2013). Seventy-four per cent of the EU's population lives in urban areas (The World Bank, 2013), and these urban areas are responsible for almost 85% of the EU's GDP (European Commission, 2007). Cities account for a significant part of economic growth, but they are also significant polluters. There is no consensus on how much cities contribute to the global greenhouse emission, but sources such as the United Nations Human Settlements Programme or official statements by cities such as London and New York estimate it around 75-80% (Satterthwaite, 2008).

Urban traffic is responsible for 40% of the total CO_2 road transport emissions and 70% of emissions of other pollutants. Two thirds of the total transportation energy used, is linked to individual mobility (TRT, 2010). The increasing traffic in European cities has resulted in congestion, which causes a loss of around yearly 100 billion Euros, or 1% of the EU's GDP, worsening air and noise pollution and growing road traffic accidents. While these problems are experienced at a local level, they have an impact on the global scale in the form of global warming, climate change, increased health problems or bottlenecks in logistic chains (European Commission, 2007). Towns are drivers of the European economy and urban productivity is interlinked with the efficiency of their transport systems. At the same time, the urban spaces, which accommodate the transport systems, also serve as the living environment for the majority of the population.

If a high quality of life should be achieved in a sustainable fashion, transport related problems, such as traffic congestion, increasing demand for mobility, difficulties for non-motorized transport, loss of public space, environmental impacts, etc. have to be faced and solved (Rodrigue, 2013 and TRT, 2010). At this point it is important to define what is meant by sustainable. In the following, the definition of Ralph Buehler will be used:

"Sustainability (…) means encouraging shorter trips by modes of transportation that require less energy and generate less harmful environmental impacts. Moreover, a more sustainable transportation system should foster commerce, reduce energy consumption and carbon emissions, increase safety, provide equal access to destinations for all groups of society, and enhance the quality of life." (Buehler, et al., 2009, p.3)

Interestingly enough, this definition does not include the aspect of reduction of the number of trips, which allows for debate whether the definition is complete.

2.2 The benefits of cycling

Bicycles have the potential to ease on the aforementioned issues in relation to urban transportation. The following is an overview of the benefits cycling has to offer to cities, which are in many cases interrelated.

2.2.1 Health benefits

Cycling, if integrated in a daily routine, can serve as physical activity. Cycling as a mode of transportation is accessible to the population, which has low levels of participation in sports and leisure-time physical activities. It can contribute to improved health, across diverse population groups, including children, adolescents, women, older adults, people with low incomes, and non-athletic people. Further benefits derive from reduced car use, which leads to improved air quality, reduced noise pollution, and reduced greenhouse gas emissions (Garrard et al., 2012). In the discussion about the health benefits of cycling, a reoccurring concern is the safety of cyclists in relation to the traffic dangers. Most scientific studies though show that the health benefits of cycling far offset the traffic dangers (Jacobsen & Rutter, 2012). Recognizing the health benefits of cycling, many Western industrialized countries have been encouraging walking and cycling as a way of travel, since the increased daily physical activity can help protect against chronic diseases and obesity (Buehler et al., 2011). These health benefits serve also as economic benefits: The regular exercise can improve the overall physical condition, which reduced the cost of healthcare (ECMT, 2004).

2.2.2 Environmental benefits

The most obvious environmental benefit of bicycles is that they are environmentally friendly, in the meaning that they are free of emissions and noise (ECMT, 2004), which leads to improved air quality, reduced noise pollution and greenhouse gas emissions (Garrard et al., 2012). A shift from car use to cycling in urban areas could contribute to less energy consumption of travel activities (ECMT, 2004). Furthermore cycling itself doesn't consume non-renewable resources, although the production of infrastructure, bikes etc. do. In general it can still be said that cycling consumes far less non-renewable resources compared to motorized transportation modes (Pucher & Buehler, 2012a). The

discussion about climate change, energy security and unstable fuel prices all raise the concern for the need of a sustainable transport strategy, in which the bicycle can play an important role for the urban future (Shaheen, et al., 2012).

2.2.3 Economic benefits

As mentioned above, shortages in oil supply and rising energy prices increase the cost of car use, which enhances the relative cost savings of cycling. The cost saving may become an important economic incentive to cycle rather than to drive (Buehler & Pucher, 2012b), while providing cost-effective transport (ECMT, 2004): it costs less than private automobiles and public transportation, both in direct user outlays and public infrastructure investment (Buehler & Pucher, 2012a). Cycling facilities, such as cycling paths and parking can be developed at lower costs than the facilities for cars. When cycling is replacing car use, the external costs can be reduced (ECMT, 2004).

Since bikes require little space for both operation and storage, a modal shift to cycling might help mitigate roadway congestion and crowding of public transport during peak hours (Buehler & Pucher, 2012b). This is important in the context of the already mentioned economic loss due to congestion, but also individual users save time, since cycling can often be one of the quickest modes of transport in urban areas, given that the distances are not too far (ECMT, 2004). There is a correlation between cities with higher rates of active modes of transportation and lower proportions of their total income spent on transportation (Tranter, 2012).

2.2.4 Social benefits

Bikes and cycling infrastructure require less space, in comparison to cars. A shift from car use towards bicycle use would allow more space for public use, with better environmental qualities, such as air quality. This could allow for improved social capital and community liveability enhancing the quality of life. These circumstances give more space for increased social interactions, while reducing crime (Garrard et al., 2012). Cycling is affordable to an overwhelming part of society, while it is physically possible for most, enhancing mobility options for all groups, even low-income households, which are often concentrated in urban areas (Buehler & Pucher, 2012b). Cycling can have limitations though for those who have physical limitations, for instance the elderly (SWOV, 2013). The availability to virtually all social groups makes cycling however a socially equitable and sustainable mode of transportation (Pucher & Buehler, 2012a).

2.2.5 Transport efficiency benefits

In congested areas and for short distances, cycling can be the fastest mode of travel. One parked bicycle takes up only about 8% of that of a parked car, while 10 bicycles can be parked in the space of a single car. Last but not least the costs related to the needed infrastructure are more for cars than for bicycles (TRT, 2010).

The definition of sustainable transportation, quoted above, pointed out following: Transportation should require less energy, generate less harmful environmental impacts, foster commerce, reduce energy consumption and carbon emissions, increase safety, provide equal access to destinations for all groups of society, and enhance the quality of life. The four categories of benefits, described above, fulfil all of the mentioned requirements to some extent, especially if in comparison with motorized transportation.

2.3 Disadvantages of cycling

While there are strong arguments in favour of urban cycling, the disadvantages should also be discussed. Most existing problems around cycling are connected to deficiencies in existing cycling infrastructure. In many countries the network of cycling road infrastructure is not maintained well enough, for instance not being cleaned from leaves or snow, which can lead to accidents. In many cases the coverage of the network is insufficient, leading cyclists through motorized traffic or pedestrians, opening the possibilities for collisions. If there are not enough cycle parking facilities at the destination of users, it can discourage people from cycling. This is in connection with the security involving the bikes, since bicycle theft is a common issue. Intermodal transport has its limitations in many countries, meaning that bicycles can either not be carried on public transportation or are strongly limited in the conditions. Weather conditions can be perceived as a limitation for cycling, but as it will be mentioned later, there are examples of cities, which have harsh weather conditions, but still maintain a high share of cyclists (TRT, 2010). Cycling can also have limitations to the elderly and the handicapped. A study showed that the elderly tend to have a higher than average fatality rate in traffic (SWOV, 2012). In Denmark for instance the statistics about cyclists killed in accidents between 2004 and 2008, show a clear correlation between aging and fatal accidents (Ehlers, 2012).

2.4 Cycling and the EU

Since both Copenhagen and Berlin are located in countries, which are part of the EU, the position of the EU in regard to cycling will be examined.

The approach of the EU towards cycling is both limited and positive at the same time. They see a big potential of cycling in urban mobility, suggesting in the Green Paper on Urban Mobility that it should become an integral part of urban mobility policies. The European Commission is involved with cycling

in the member counties in the following areas: Addressing road safety policy, managing funding instrument, promoting the exchange of best practices and supporting the development of local cycle policies (European Commission, 2013). Following is a short description of the various efforts by the European Commission.

According to the European Economic and Social Committee, the funding available for EU members are from the European Regional Development Fund (ERDF), The European Agricultural Fund for Rural Development (EAFRD), Intelligent Energy Europe (STEER) programme, The EU Research Framework Programmes, with its key initiative being CIVITAS, and the Programme of Community Action in the Field of Health (EESC, 2013). The European Cyclist Federation has identified around 6 billion of Euros worth of European Union funding available for cycling related initiatives in the EU (ECF, 2013).

ELTIS, "The urban mobility portal" is the homepage, created by the European Commission, in order to showcase over 200 case studies on cycling across Europe, enhancing the exchange of information within Europe. The information should help create urban transport systems, using less energy and producing less emission, while improving the quality of life, competitiveness of urban areas and mobility (ELTIS, 2013).

STEER is a branch of the Intelligent Energy - Europe programme, co-funding projects in relation to policy audits and development of local cycle policies (BYPAD, SPICYLES, etc.), knowledge transfer (ASTUTE, OBIS, STREAM, etc.) and campaigns for behavioural change (CONNECT, TRENDY TRAVEL, etc.) (European Commission, 2013).

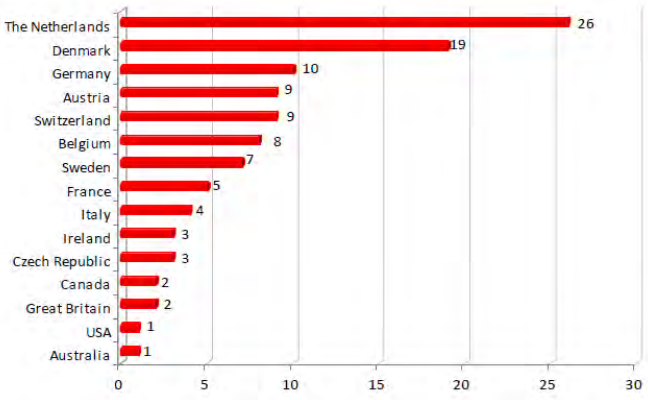
INTERREG offers the opportunity for regional cooperation across Europe, with the aim to improve the effectiveness of regional policies and instruments. The programme is funded through the European Regional Development Fund (INTERREG IVC, 2013).

Civitas, co-financed by the European Union, is aimed at supporting cities in order to introduce policies and measures towards sustainable mobility, achieving a significant shift in the modal split towards sustainable transport. This is encouraged through both innovative technology but also policy based strategies (CIVITAS, 2013).

While there are multiple options to receive support from the European Union, from co-funding, knowledge exchange to policy advice, there are no compulsory legal or financial frameworks for the EU member states in regard to a national bicycle plan (TRT, 2010). This lack of frameworks allows for very different cycling rates and policies among cities throughout the European Union (Buehler & Pucher, 2012b).

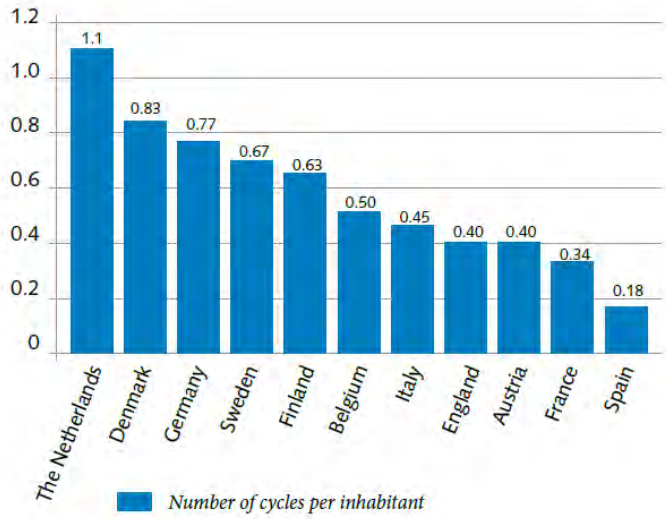
2.5 Cycling in numbers in the EU

The level of cycling doesn't only vary in different countries. There can also be strong variations between cities, within the same country. When looked at a country scale in the EU, the Netherlands score the highest share of bicycle use, with 26%, with the bicycle rates varying between municipalities from 15 to 40%. Denmark follows this, with 19%, while the differentiation among cities in this case is not so big. Germany follows with 10%, typically with a higher bicycle use in the western federal states (Fietsberaad, 2009). All of the aforementioned numbers are referring to the bicycle share of all journeys. The following graph shows some European countries and their bicycle usage.



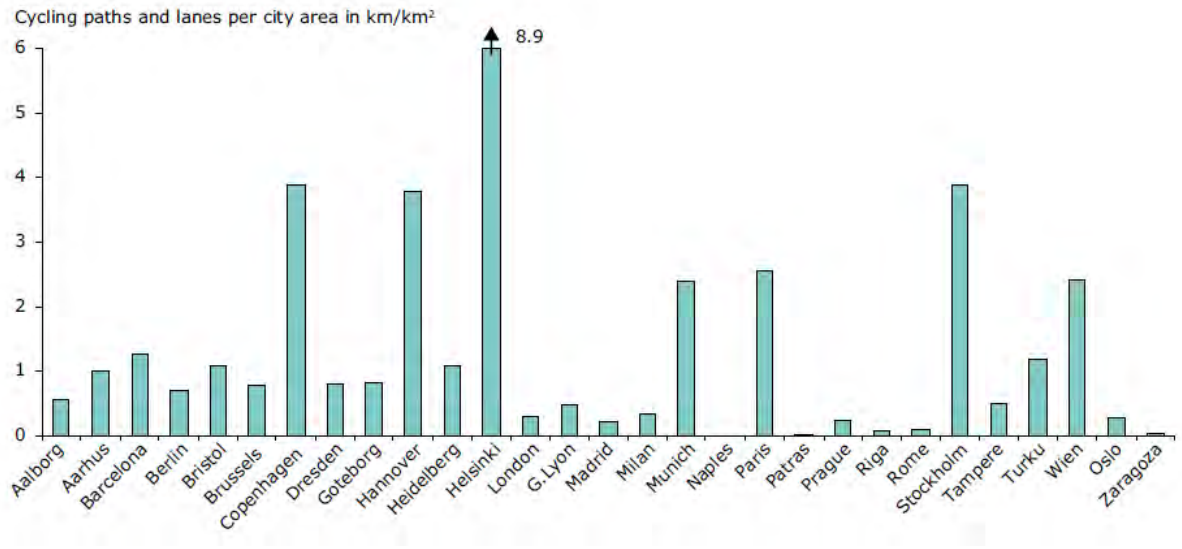
Graph 1: Bicycle modal share of all journeys (TRT, 2010)

The ownership of bicycles in selected European countries show similarities to that of the modal share, the top three countries being the Netherlands, Denmark and Germany. The graph shows the number of bicycles per inhabitant, meaning that in the Netherlands there are more bicycles than inhabitants.



Graph 2: Bicycle ownership per inhabitant (Dutch Bicycle Council, 2006)

Not only is there a big difference in the modal share of cities, there is also a big difference in the infrastructure available for cyclists. The following graph shows the km of cycle path and lanes per square km in European cities. The leading cities are Helsinki, Stockholm, Copenhagen and Hannover, although it is important to point out that Amsterdam is not represented on the graph.



Graph 3: Cycling paths and lanes in some cities (km/km^2) (TRT, 2010)

3 Factors influencing cycling behaviour

The following chapter analyses the different aspects that influence cycling behaviour in cities. The different factors are categorized into two groups. One of the groups includes factors, which directly influence built road infrastructure, while the second group includes factors which don't directly affect the road infrastructure. Factors in the first group are: Types of cycling road infrastructure, intersection design and lights, safety and separation, traffic calming and land use planning. Factors in the second group are: Bike sharing, bicycle parking and security, health and social status, weather and topology, government and policies. This differentiation is made keeping the research question in mind and being able to set a higher focus on factors, which will play an important role in developing infrastructural recommendations for Berlin. This chapter also shows that there are many limitations to the recommendations developed in this research, as mentioned in the "Research constraints", since cycling levels are dependent on many factors, some being even crucial, for instance financing. The definition for cycling infrastructure includes cycle lanes, tracks, paths, greenways, intersections, etc., basically those elements, which play a role during the act of cycling (Andersen et al., 2012).

3.1 Factors directly influencing cycling road infrastructure

3.1.1 The types of cycling road infrastructure

The categorization of the types of bicycle route facilities varies in different sources. Following is a list of the different typologies, in order to have a clear understanding of the exact definitions. Furthermore the facilities are grouped according to the level of separation: shared streets and shared lanes, bike lanes, separated paths and standalone paths (Furth, 2012).

3.1.1.1 Shared streets and shared lanes

Shared streets and shared lanes are defined as there not being any dedicates cycling space.

3.1.1.1.1 Bike routes using quiet streets

Local streets are important because they typically have low traffic levels and speed, while they are necessary for users to reach the cycling network. They can additionally be used in order to create main bicycle routes. The two approaches to create these are either by using a continuous street and applying traffic calming measures or by connecting discontinuous local streets using bicycle-pedestrian links (Furth, 2012).

3.1.1.2 Bike lanes

Bike lanes are defined as a part of the roadway, designated for the exclusive use of cyclist. The marking can consist of striping, signage or pavement marking, while there is no physical barrier separating the bike lanes from other modes of transportation (NACTO, 2013). It is an inexpensive and space-efficient type of cycling facility, although the close proximity of motorized traffic can make riding on them stressful. Since there is no barrier along the bike lanes, potential dangers are illegal parking or so called "dooring", which means that passengers open the doors of vehicle's in the way of the cyclist, which leads to a collision. For this reason they are not recommended in combination with parking lanes, but if necessary, at least a buffer zone between parking and cycling is recommended. Because of these dangers, for instance the Dutch design manual only recommends cycling lanes for roads with two lanes and no parking lanes (Furth, 2012).

Image 1: Bike lane in Berlin (own image)

3.1.1.2.1 Conventional bike lanes

Conventional bike lanes are as described above, designated for cyclists marked by pavement markings and signage. The lanes flow in the same direction as motorized traffic, while they are typically located on the right side of the road, between the road and the parking lane or curb (NACTO, 2013). The following three categories are basically very similar to conventional bike lanes, but differ in only one aspect.

3.1.1.2.2 Buffered bike lanes

The buffer lanes differentiate from the conventional bike in the fact that the lanes are complemented with space, which separates the cycling lane from motorized traffic (NACTO, 2013). This measure can make the lanes wider, which creates a higher level of separation from motorized traffic, making cycling less stressful (Furth, 2012).

3.1.1.2.3 Contra-Flow Bike Lanes

Contra-flow bike lanes allow cycling in the opposite direction of motorized traffic. While in one direction both motorized vehicles and bicycles are allowed, the other is only permitted for bikes (NACTO, 2013). Legalizing contraflow cycling avoids around-the-block routes and reduces sidewalk cycling, while at the same time shortening travel times for cyclists. The danger of "dooring" is less than riding with the flow, since one is driving along the passenger side doors, which are used less

often, the car occupant is faced towards the cyclist and if collision happens, the direction of the collision will tends to close the door instead of opening it (Furth, 2012).

3.1.1.2.4 Left-Side Bike Lanes

Left side bike lanes differ from conventional bike lanes in the fact that they are placed on the left side of one-way streets (NACTO, 2013).

3.1.1.2.5 Advisory lanes

Advisory lanes differ from the aforementioned lanes in the fact that they are not exclusively designated for cyclists. Advisory lanes are implemented in the case, that a road is too narrow to mark conventional bike lanes. The street is divided into a central driving area and two side lanes for cyclists although the central driving lane is not wide enough for two cars. When meeting opposing traffic, the cars are allowed to enter the cycling lane, but only if there is a gap in the cyclists traffic (Furth, 2012).

3.1.1.2.6 Shared bus lanes

Shared bus lanes are bus lanes, which also accommodate cyclists, but because of the common use, extra width of the lane is necessary (Pucher & Buehler, 2012b).

3.1.1.3 Separated paths / Cycle tracks

Separated paths or cycle tracks, mean that the designated cycling space is physically separated from motorized traffic, either by a curb or by parked cars. They form a substantial part of the cycling network in Danish cities, as in Copenhagen. When riding on cycling tracks, individuals only have to pay attention to traffic at intersections. It is important to have a safe design at intersections, to avoid accidents among cyclists and motorized vehicles (Furth, 2012). Cycle tracks tend to lead to an increased vulnerability at intersections. Cycle tracks may face capacity issues, which can lead to difficulties in overtaking. The design should avoid such difficulties since they lead to both dangerous situations and insecurity (Andersen et al., 2012). Conflicts between pedestrians and bus passenger can occur, especially when tracks are not differentiated. Cycle tracks should typically be placed on roads with longer blocks with few cross-streets (Alta, 2009).

3.1.1.3.1 One-Way Protected Cycle Tracks

One-Way protected cycle tracks are paths, which are located at street level, while there is a physical protection from traffic. Usually a parking lane, but other barriers are also possible, protects cyclist from motorized vehicles (NACTO, 2013).

3.1.1.3.2 Raised Cycle Tracks

Raised cycle tracks are vertically separated from traffic and can be either one-way or two-way. The level of the cycle track can either be on the same level as the sidewalk or in between the sidewalk

and road. There is also a possibility of combining it with barriers, such as parking lanes (NACTO, 2013).

Image 2: Two-way cycle track in Copenhagen (own image)

3.1.1.3.3 Two-Way Cycle Tracks

Two-way cycle tracks are physically separated cycle tracks, but with the difference that they allow bicycle traffic in both directions. It can be both at street level and raised (NACTO, 2013).

3.1.1.4 Standalone paths

Standalone paths are bike paths in an independent right of way, typically in green settings in parks, along rivers and canals or abandoned rail tracks. Dual systems, with two paths, both for cyclists and bikes are common in Europe and often heavily used for commuting (Furth, 2012).

For all of the cycling infrastructure mentioned above it is important that they have a smooth and even surface, which allows for a constant speed and comfort while cycling. This implies a regular maintenance of the facilities. Generally asphalt is the most suitable, while paving slabs tend to become uneven with time. For this reason paving stones and slabs should be avoided, except for limited spaces in order to focus attention (Andersen et al., 2012).

3.1.2 Intersection Design and lights

Intersection design should receive special attention, since this is where most accidents between cyclists and motorized vehicles happen. The aim is to develop them in a safe way, which also makes cyclists feel secure. A good design is considered if shortened cycle tracks are turned into cycle lanes for the intersection, or if the cycle track leads up to the intersection. Set back stop lines for cars are also advised (Andersen et al, 2012).

Further in order to assure a fast cyclist flow, intersections should not pose unnecessary delays. The traffic lights should give cyclists priority (Andersen et al., 2012).

3.1.3 Safety and separation

A recurring theme in the discussion about cycling safety is in relation to traffic dangers, however most scientific studies show that health benefits of cycling offset the traffic dangers. The danger of motorized transportation is considered the most important issue of cycling safety (Jacobsen & Rutter, 2012). Due to the proximity of motorized traffic to cycling, cyclists may perceive, especially under poor cycling conditions a greater risk, which will discourage them from cycling (ECMT, 2004). The perception of safety while cycling is strongly connected to the built infrastructure especially with the separation of motorized traffic and cycling. According to a study written for the European

Commission, separate infrastructure is essential in avoiding conflicts (TRT, 2010). A "self-evident road"-design, which concentrates the user's attention to conflict areas, is necessary instead of an environment in which users act as a reaction to fear (Andersen et al., 2012). The mainstream population is not tolerant towards traffic stress, which makes separation necessary in order to reach high levels of cycling. The need for separation can also be recognized in the correlation between separated cycling infrastructure and the share of cyclists. Countries with the highest level of cycling have infrastructure, which separates motorized traffic from cycling (Furth, 2012). At the same time cities with the highest bike share also have the safest cycling. This phenomenon has causation likely running both ways: safer cycling motivates more cycling, while more cycling leads to greater safety (Buehler & Pucher, 2012b). The idea of more cycling leading to greater safety is also called "Safety in numbers". It has to be pointed out though, that in order to reach higher levels of safety, a critical mass of cyclists has to be reached. It could happen that in places where very few cycle, if the share grows the number of accidents will as well (Andersen et al., 2012). The Dutch Design Manual for Bicycle traffic recommends physical separation with any streets with over two lanes. This aspect of perceived and real safety and separation will be an important factor throughout this work, because it is essential in order to achieve a high cycling share in the population.

3.1.4 Traffic Calming

Cyclist can feel safe without cycle-specific infrastructure if the traffic speed surrounding them is low enough. Low traffic speed both reduces the chance of an accident while reducing the degree of injury in case of an accident (Cycling England, 2011). There is a high dependence of the impact speed of an accident and the risk: 50 km/h has twice the risk as at 40 km/h while having a five times higher risk than at 30 km/h (Rosén & Sander, 2009). With the help of traffic diversion, averting through traffic, historic city centres have the potential of creating a low-stress environment for cyclists (Furth, 2012). Traffic calmed streets have the potential of linking otherwise unconnected cycle tracks and lanes (Buehler & Pucher, 2012b).

3.1.5 Land use planning

A Danish study showed that that land use planning has a strong effect on cycling. Especially topography, population density and the size and location of urban functions are factors influencing the level of cycling (Jensen, 2013).

3.1.5.1 Density and distances

The distances between different functions can influence the level of cycling. For instance urban sprawl tends to increase distances, which can discourage from cycling (ECMT, 2004). Urban density increases bicycle traffic (Andersen et al., 2012), while there is a clear tendency of dropping bicycle

share as the travel distance grows (Buehler, et al., 2009). A study has shown that a greater trip time has a significantly negative effect on the attractiveness of cycling. The cycling facility type can make a big difference in the perception of the cyclists. The study points out that for a typical cyclist, one minute of cycling in mixed traffic is as demanding as 4.1 minutes on bike lanes or 2.8 minutes on cycle tracks (Hunt & Abraham, 2007). The distance between different functions is also connected to urban density. A study has showed that more densely populated towns have a higher level of cycling (Jensen, 2013).

The majority of urban trips are over short distances, which makes non-motorized modes of transportation a viable option for urban mobility (Rodrigue, 2013). Higher population density and greater mixes of land use lead to shorter trips, while also making public transportation more viable and decreasing average car speeds. If employees live close to their workplace, the amount of people choosing to cycle will rise (Jensen, 2013). On the other hand density can also lead to higher traffic volumes, potentially discouraging from cycling. Historically Northern-European countries have a longer tradition of mixed-use zoning and transit oriented developments (Buehler & Pucher, 2012b).

A general aim should be to shorten transport distances for shopping facilities, which means that newly designated shopping areas should be located in central areas of the city. The redevelopment of abandoned but central areas, for instance port areas can contribute to cycling, if the number of car parking spaces is kept low (Andersen et al., 2012).

3.1.5.2 Network density

In order to create a successful cycling infrastructure, it must guarantee travelling to a destination convenient, quick and safe (Andersen et al., 2012). For this reason it is important that the routes must create a network. This network should connect neighbourhoods with destinations such as train stations, educational facilities, workplaces, consumption places and recreational areas (Furth, 2012). A recommended network mesh is between 400 to 500 meters in urban areas, although in the city centre this mesh can be denser and in the periphery more sparse (Andersen et al., 2012). Then again, there is a difference between a complete network and a high network quality. Quality is typically defined by the traffic design, which cannot be identified based on rough data, such as the aggregated length of cycling infrastructure (Dutch Bicycle Council, 2006). When planning the network, cycling infrastructure should not be created where it is convenient and cheap but where it is necessary, while being convenient, logical and direct (Andersen et al., 2010).

3.2 Other factors

3.2.1 Bike sharing

Bike sharing is a short term bicycle access system. While the first bikesharing program was launched in the Netherlands in the 1960's, there has been a growing interest in recent years. In 2011 there were around 136 programmes in 165 cities, with 237,000 bikes available (Shaheen & Guzman, 2011). There have been three generations of bike sharing: The first generation is called White Bikes. This was based on the first programme in Amsterdam, where 50 bikes, painted white, were freely spread across the city, unlocked, for people to use. The second generation is called the Coin-Deposit System. This system already had specific docking stations in which bikes could be locked and a small deposit (coin) was needed to unlock them. The third generation is the information technology–based systems. This system also works with docking stations but also with a kiosk or user interface technology for checking bikes in and out and are usually complemented with advanced technology, for instance smart cards, mobile phones, etc. (Shaheen, et al., 2012).

3.2.2 Bicycle parking and security

Safe bicycle parking at the destination has an important effect on cycling behaviour (Hunt & Abraham, 2006). It is not only essential to provide cycling facilities but they should also be perceived as safe and adequate by users (ECMT, 2004).

3.2.3 Health and social status

The proximity of vehicle exhaust can be considered as a health hazard (ECMT, 2004). A study has shown however that roadway design can influence the level of exposure to vehicle exhaust. The design of a cycle track may be more protective for cyclists than bicycle lanes, when they measured microscopic ultrafine particles in vehicle exhaust (Kendrick et al., 2011).

The social status of cycling varies in different countries. It can be seen as an activity for children, a recreational activity, or simply an inappropriate mean of transportation for those who have a car. The European Commissioner for the Environment went as far as saying that the worst enemies of the bicycle in urban areas are long-held prejudice (ECMT, 2004).

3.2.4 Weather and topology

Weather conditions, such as extreme temperatures or high precipitation can be a barrier for cycling, although there are examples which show, that even in unfavourable climates cycling is chosen by users (ECMT, 2004). A study showed that both differences in temperature and daylight hours influence transport choices. People tend to cycle less in extreme temperatures, while in some cases women tend to avoid cycling in dark (Andersen et al., 2012).

Areas consisting of a hilly terrain might be conceived as unsuitable for cycling (ECMT, 2004). Basically in a flat town more will cycle and fewer will choose the car as their mode of transportation (Jensen, 2013). A hilly terrain in comparison to a flat terrain can half cycling levels: In the flattest parts of Denmark there is a 21% modal share of cycling, while in the hilliest it is 10% (Andersen et al., 2012).

3.2.5 Government and policies

The different levels of government play an important role in making cycling a relevant mode of transportation for the public. An increasing number of countries are developing a national cycling plan, although not mandatory under EU regulations. These plans, if tailored to specific circumstances can be the framework for long term developments and implementation of cycling policies, integrating various levels of government and sectors (ECMT, 2010). In order create attractive and safe cycling, local and regional authorities have to fully integrate them into urban mobility policies (European Commission, 2007). Continuous cycling policies with an integral traffic policy, including cycling, can be associated with a higher level of bicycle use (Dutch Bicycle Council, 2006). One measure alone is not enough for success: well-coordinated infrastructure provisions, promotional programs and transportation and land-use policies have proven successful in cities with high levels and safety of cycling. Since local authorities (i.e. cities) are in charge of the implementation of cycling policies, it is important to analyse cycling trends at the local level (Buehler & Pucher, 2012b). These authors summarized what has to be considered in order to achieve a successful implementation of cycling policies.

Infrastructure, policies, and programs to increase cycling	Implementation strategies
1.Provide a comprehensive package of integrated measures	1.Publicize both individual and societal benefits
2.Build a network of integrated bikeways with intersections that facilitate cycling	2.Ensure citizen participation at all stages of planning and implementation
3.Provide good bike parking at key destinations and public transportation stations	3.Develop long-range bike plans and regularly update them
4.Implemetation of bike sharing programs	4.Implement controversial policies in stages
5.Provide convenient information and promotional events	5.Combine incentives for cycling and disincentives for car use
6.Introduce individualized marketing to target specific groups	6.Build alliances with politicians, cycling organizations, and other bike friendly groups
7.Imporve cyclist education and expand bike-to-school programs	7.Coordinate bike advocacy and planning through national organizations
8.Improve motorist training, licensing, and traffic enforcement	

9.Restrict car use through traffic calming, car-free zones, and less parking	
10.Design communities to be compact, mixed-use, and bikeable	
Source: Buehler & Pucher (2012b)	

3.2.5.1 Information and Networking

Since developing cycling happens on a local level it is important that a framework for knowledge exchange is created, just as it happens at the EU level.

3.2.5.2 Finances

Although the cost of developing a bicycle network is not expensive in comparison to railway or highway projects, a considerable investment is needed (Furth, 2012). Typically, when cycling is marginal in transport policy discussions, it is reflected in the national budgetary allocations for cycling (ECMT, 2004). Cycling action plans are often insufficiently funded, public debate though can help focus political attention on the issue, resulting in higher funding. Co-financing both at a state and EU level is a possibility (Andersen et al., 2012).

There are some specific measures, which can help achieve the necessary funding. Laws and policies can integrate cycling, in that they require cycling infrastructure on road construction projects. Planning regulations furthermore can require that land development projects include cycling infrastructure. A possibility to cut costs of individual cycling infrastructure projects for governments is to include the cycling infrastructure in other projects (Furth, 2012).

The estimated cost for building new paths ranges from $300.000 to $1.5 million per mile ($200.000 to $1.000.000 per km) or more if bridges are involved. The higher the level of the separation of cycling infrastructure involves higher construction costs and takes up more space, which is the reason for governments tending to prefer lower levels of separation (Furth, 2012).

4 Case Studies

4.1 Copenhagen

The two chosen case studies are both European capitals. Copenhagen, the capital of Denmark, is a city with around 562,000 inhabitants, while the Copenhagen region consists of around 1.7 million inhabitants. There is not only a considerable difference between the population of the city and the region but also in the surface. While the surface of the city is only 77.2 km^2 the surface of the region is 2,553.10 km^2, which is about 33 times larger. Based on these numbers the population density of Copenhagen is 7283 inhabitants per km^2 and 670 per km^2 for the region. When looking at the literature the numbers especially on the region vary a lot, probably because of the difference in defining the area of the region. All of the numbers above are from the official statistic homepage of Denmark and for the year 2013 (Statistics Denmark, 2013).

Image 3: Copenhagen region (Region Hovedstaden, 2013; own visulaization)

A special feature of the city of Copenhagen is the municipality of Frederiksberg. Frederiksberg, although surrounded by the city of Copenhagen is its own town and for that reason is handled administratively and statistically separately (Frederiksberg Kommune, 2013). Its surface is 8 km^2 and has a population of 102.306 (Statistics Denmark, 2013). Since Frederiksberg is embedded in the urban structure of Copenhagen, it will be considered as a connected urban fabric, although because of the administrative separation, some of the following maps might exclude Frederiksberg.

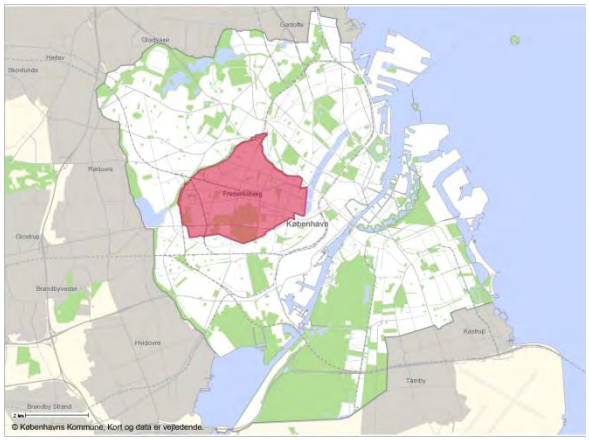


Image 4: The location of Frederiksberg (Københavnerkortet Københavns Kommune, 2013)

Seventy per cent of the households in Copenhagen are car free and 7% of the population is students. 70 cm of rain falls on average per year, there are on average 76 days a year with temperatures under 0 Celsius and on average no days higher than 32.2 Celsius (Buehler & Pucher, 2012b). The total network of roads in Copenhagen has a length of 700 km, 24 km of those being highways and 2km expressways (Statistics Denmark, 2013).

4.2 Berlin

Berlin, the capital of Germany has a population of 3,501,872, while the region Berlin-Brandenburg has a population of 5,997,507, according to the last numbers of 2011 in the database of the statistical homepage of Berlin Brandenburg. The surface of the city is 891.7 km^2 while the region is 29,484 km^2 (Amt für Statistik Berlin-Brandenburg, 2013). The density based on these numbers for the city is 3927 inhabitants per km^2 and 203 in habitants per km^2 for the region.

Image 5: Overview of the region Berlin-Brandenburg (Land Brandenburg, 2013)

Fifty percent of the households are car free, while 4 percent of the population is students. It rains 57 cm of rain on average per year, while there are 80 days with temperatures below 0 Celsius and 7 days over 32.2 Celsius (Buehler & Pucher, 2012b). The road network of Berlin has a total length of 5,421 km, while the region has all together 17,760 km. The elevation of the city moves between +34 m and +60m. The furthest East-West points of the city measure a distance of 45 km, while the North-South points measure 38 km (Amt für Statistik Berlin-Brandenburg, 2013).

Image 6: An overview of the districts of Berlin (Berliner Bezirke, 2013)

Berlin consists of 12 districts, the lowest population being 226,914 inhabitants in Spandau and the highest being 372,295 in habitants in Pankow (Berlin.de, 2013). The smallest district is Friedrichshain-Kreuzberg, being 20.16 km^2 with a population of 274,500 inhabitants making the density 13,616 inhabitants per km^2 in 2011 (Berlin.de, 2012a). Treptow-Köpenick is the largest district, being 168.41 km^2 with a population of 244,701, making the population density 1453 inhabitants per km^2 (Berlin.de, 2012b).

The map on the right shows the population density of the various districts of Berlin. The districts with the lowest densities are between 1,000 up to 3,000 inhabitants per km^2 while the highest ones have over 5,000.

Image 7: Population density in Berlin per district (Land Brandenburg Regionalmonitoring, 2013)

4.3 Berlin and Copenhagen in comparison

When comparing the information about the two capitals, there are similarities in the topography and the weather conditions. While there is more percipitation in Copenhagen on average, there are more days in Berlin with very high or low temperatures. Berlin also has a lower percentage of both car free households and students. The striking difference between the two cities is in their size. Copenhagen as a city is defined as a reather small area, 77.2 km^2, when including Frederiksberg around 85.2 km^2. The biggest district of Berlin alone is around twice the size of Copenhagen, which is an essential factor when transferring the guidelines of Copenhagen to the Berlin case study. To demonstrate the difference in size, two images in the same scale were taken, one from the city of Berlin and one from Copenhagen and the layered, to show the difference in dimensions. It also can be observed though that the borders of Copenhagen have been defined rather small in comparison to the urban structure. With the help of a satellite photo it can be seen that the urban structures directly in connection to the city, reach far beyond the official borders. The image on the right shows in white, the official city borders, while the red marking shows the urban fabric surrounding it.

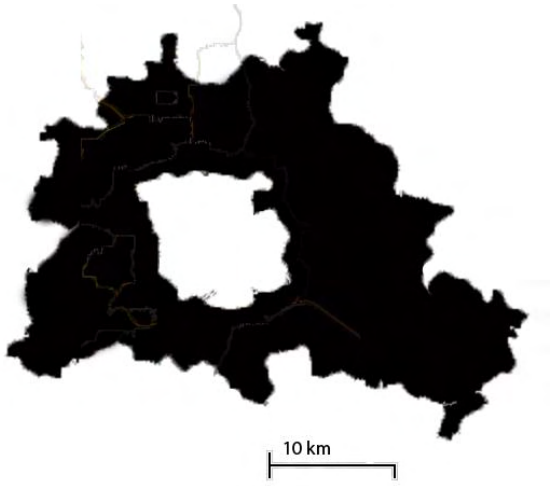
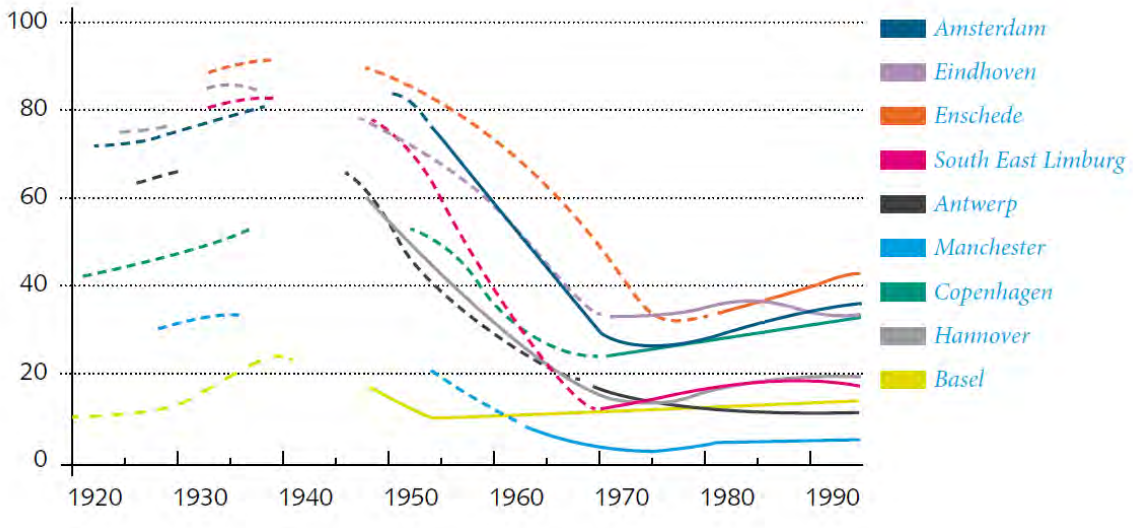


Image 9: The black marking shows the outlines of Berlin while the white marking in the middle is the outline of Copenhagen (Own image)

Image 8: Urban structure surrounding the city borders (Google Maps, 2013; own visualization)

4.4 Short historic perspective of cycling

The following graph shows a reconstructed trend line of bicycle usage from the 1920's onwards in Europe. The curves represent the developments, according to which after 1900 the bicycle transformed from a recreational product for the elite, to a mass product for all social classes. Until the 1950s most graphs show a positive trend and a relatively high percentage of bicycle use, especially in comparison to current cycling trends. The sharp decline in the 1950s and 60s is connected to the increasing motorization levels and the automobiles rapid advance in urban environments (Dutch Bicycle Council, 2006). Further factors responsible for this decline were sprawling urban development and car use favouring government policies, typical of most western European countries. Some cities show a decline of bike trips between 85-14%. The increased car use in cities continuously led to pollution, congestions and accidents. As a reaction to these new developments, many German, Dutch and Danish cities chose to restrict car use, while increasing its cost. Public transportation, walking and cycling was promoted at the same time. After the 1960s there is a stabilisation of bicycle use followed by a slow but positive trend. During this positive trend there was also a negative trend of from the 1970s in the annual number of cyclist fatalities, which supports the theory of "safety in numbers (Buehler & Pucher, 2012a). The development trends can be seen on the following graph. Although the different cities have varying levels of cycling, the parallel developments are clearly visible.



Graph 4: Reconstructed modal share of cyclists (Dutch Bicycle Council, 2006)

There is a differentiation among two types of cities: Cities with a high bicycle share, with more than 30%, such as Amsterdam and Copenhagen and cities with a low share of bicycle use, with 10% or less, such as Antwerp or Manchester. Cities with a high share of bicycle use are typically cities, where extensive public transportation was not introduced in early years, while the bicycle was respected as

a regular component of traffic policy. If the cyclists were integrated in the traffic policies of the 1950s and 60s, the development of the automobile infrastructure did not occur at the expense of the cyclists and the collective image of the bicycle stayed positive. Cities with a low bicycle share can be explained by a combination of car oriented traffic policies and a well-functioning public transportation network (Dutch Bicycle Council, 2006). After drawing up the general trends of western European cities, the history of the two case studies is briefly described.

4.4.1 Historic perspective Copenhagen

The first wooden bicycles without pedals appeared in Copenhagen around the 1860-1870's, available mostly to the upper classes. The first bicycle path was created along the Copenhagen Lakes in 1880 and the first bike lane in 1910. Between 1890 and 1910 the "Safety" design bike, which we know today appears and the number of cyclists exponentially increases (City of Copenhagen, 2009). The use of the bicycle soon spread to the general public, especially during the 1920s and 1930s, allowing mobility to those who had poor access before. An important factor in the growing use of bicycles was that while the city of Copenhagen in 1920, only had 225,000 inhabitants, by 1950 the population has risen to 770,000. For the newly arriving population bikes were easily accessible for mobility needs. By 1934 already 130 km of cycle path has been built, mainly along arterial roads. After 1945 the focus was set on segregation of different transportation modes on the road space (Dutch Bicycle Council, 2006). In the first half of the 20th century Danish cities were dominated by bicycles, all social classes, on a large scale choosing this mode of transportation. This trend lasted until the 1950s, when car ownership started rising, due to the increased standard of living and the introduction of new machinery. The expansion in car use partially developed on the cost of cycling and the elimination of bike lanes (Denmark.dk, 2013a). At the same time, as car traffic started growing, congestion, pollution, accidents and the loss of cycling dominance raised concern in the population. The environmental movement and the oil crisis were important factors in re-debating transportation modes for Danish cities, leading to large investments in bike friendly infrastructure (City of Copenhagen, 2009). The 1970's and 1980's were characterized by conflicts between cycling and car interests, which led to a planning mentality, integrating cars, public transport, cyclists and pedestrians (Ruby, 2013). The expansion and improvement of the already existing large network of cycling infrastructure contributed a lot to the rebound in cycling. The reorientation of planning towards cycling can be seen in the development of the users but also in the annual cycling fatalities, decreasing between 1970 and 2008, by around 70% (Buehler & Pucher, 2012a). According to Niels Jensen the high modal share of cyclists has a lot to do with tradition and cycling infrastructure, which has been in place for years. The history of cycling in Copenhagen is very similar to the developments of Western European countries, as described earlier, although the developments following the 1960's were fairly successful.

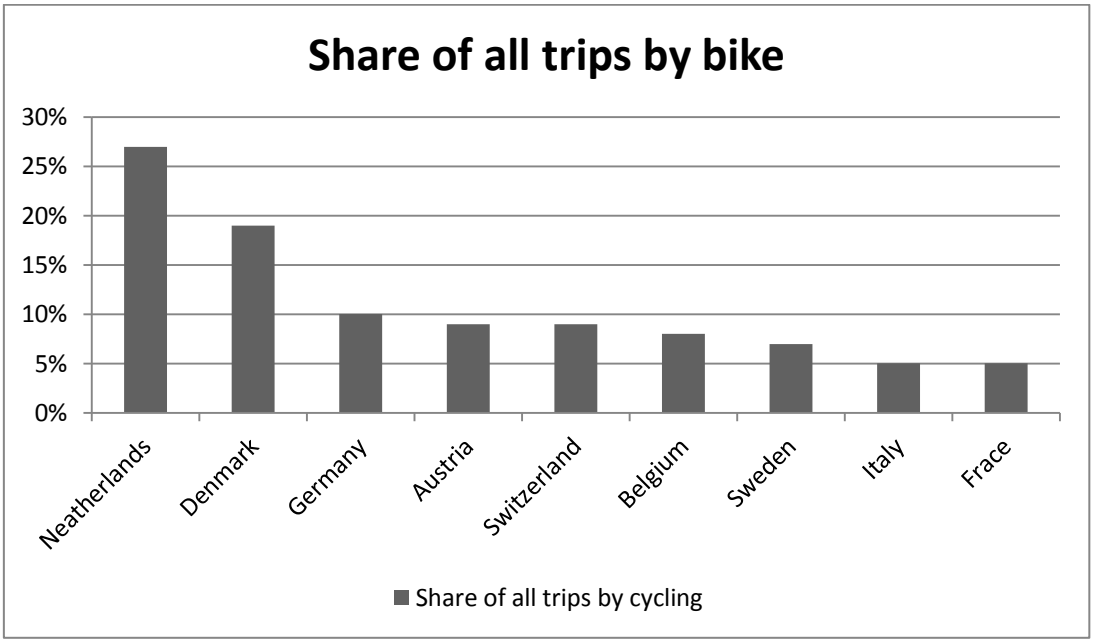
4.4.2 Historic perspective Berlin

The history of cycling in Berlin has a similar development than in most Western European countries. While cycling is first available for the upper class, in the first decades of the 1900's it soon spreads throughout society, offering an easily accessible form of mobility. Well after the Second World War cycling was the main mode of transportation for the city, until motorization became widespread and accessible for many (Raabe, 2012). With the arrival of the high levels of motorization and a shift in urban planning, cycling levels started to fall drastically. The number of bike trips in Berlin between the years of 1950 and 1975 fell by 78% (Pucher & Buehler, 2008). The following graph shows the drop in cycling up until the mid-seventies. The base year is 2001 (=100%), when the first all-year bicycle traffic count was made. After the mid-seventies, cycling saw a rebound and between 1975 and 2008, daily bike trips increased by 300% (Buehler & Pucher, 2012a).

Graph 5: Bicycle use in Berlin (Horn, 2009)

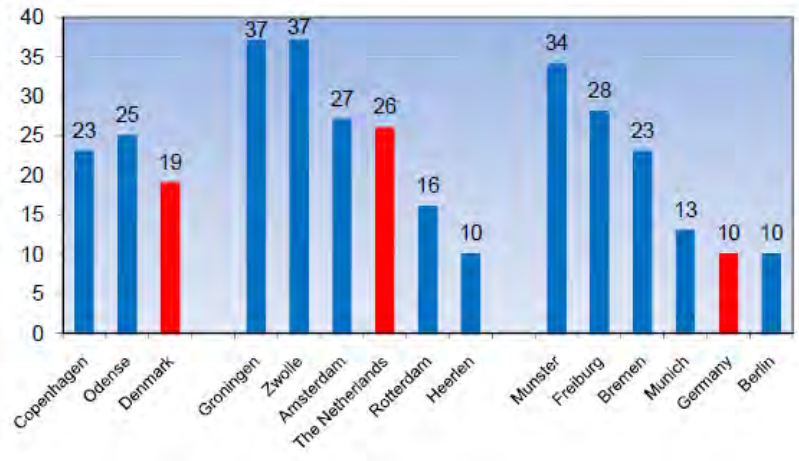
4.5 Share of cycling

As already mentioned there can be big differences in the level of cycling in various EU countries. While in the Netherlands 26% of all trips are on cycle, in Great Britain this number is only 2% (Fietsberaad, 2009). A Dutch person cycles 2.3 km a day on average, while in Spain this is only 0.1 km (EESC, 2011). When looking at the leading countries in the EU for cycling, the list is typically topped by the Netherlands, Denmark and Germany, but with fairly big differences, as can be seen on the graph below.



Graph 6: Share of all trips by bike (Kurt, 2008; own visualization)

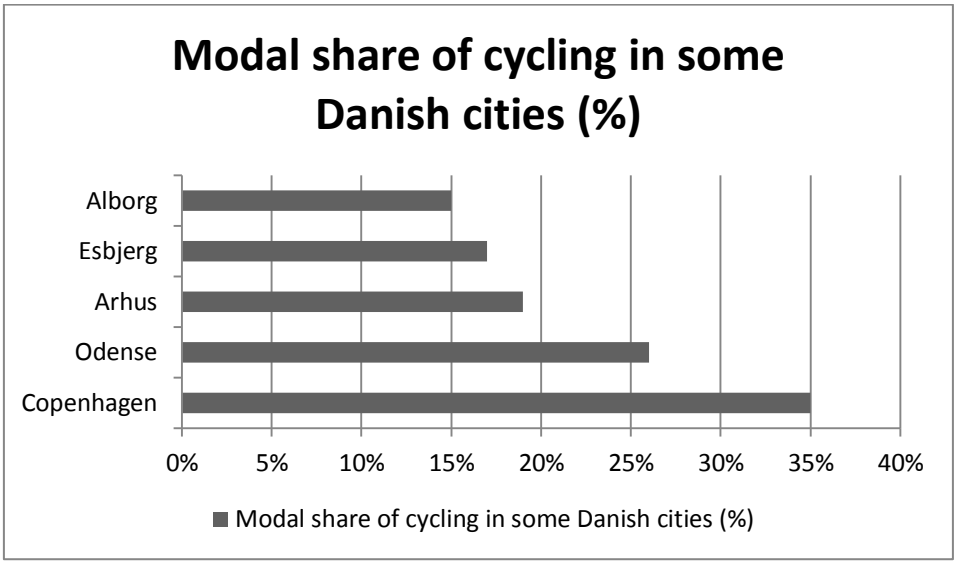
It can be generally said that in Western Europe approximately 5 to 10% of all trips are made on bicycle while in Eastern and Central Europe 1 to 5% (ECMT, 2004). Differences between cities in a specific country can vary a lot as well. The following graph shows the different modal shares of some cities in the selected case study countries and the Netherlands. The modal share of Denmark is 19%, while the modal share of Copenhagen is 23%. The differences in the German examples are bigger. While Germanys bicycle modal share is 10%, some cities such as Munster have a much higher share at 34%. Berlin lies though on the national average with 10%.



Graph 7: Bicycle modal share in some cities compared to the national average (TRT, 2010)

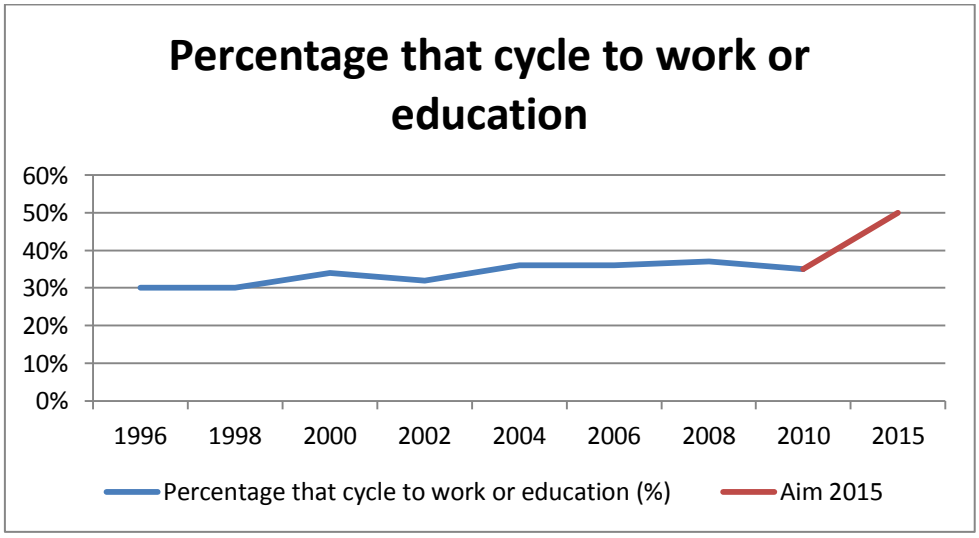
4.5.1 Share of cycling Copenhagen

As mentioned earlier, various sources quote various numbers for the cycling share, this is also the case for Copenhagen. The modal share of cycling is Denmark is 19%, but individual cities have varying levels. The modal share of bicycles for Copenhagen in 2006 was around 35% depending on the source used.



Graph 8: Cycling shares in some Danish cities in 2006 (Pucher & Buehler, 2012a; own visualization)

35% of the metropolitan area commuters of Copenhagen choose their bike to reach their school or workplace, but when looking at those who live in the borders of the city of Copenhagen, the number is 55% (City of Copenhagen, 2009). Since 1996 there has been a growing trend in the percentage of those who cycle to work or to their education: In 1996 this was 30%, reaching a highpoint at 37% in 2008 and in 2010 falling back slightly to 35%. The aim of the city is to raise this percentage by 2015 to 50%.



Graph 9: Percentage that cycle to work (City of Copenhagen, 2010, own visualization)

The high prevalence of commuting shows on the bicycle count, which is observed on a daily weekly and yearly basis. The hourly counting shows two clear peaks, which are due to the commuting traffic in rush hour. On the weekly counting it is visible that on the weekends, when people don't commute to their jobs, the cycling traffic drops.

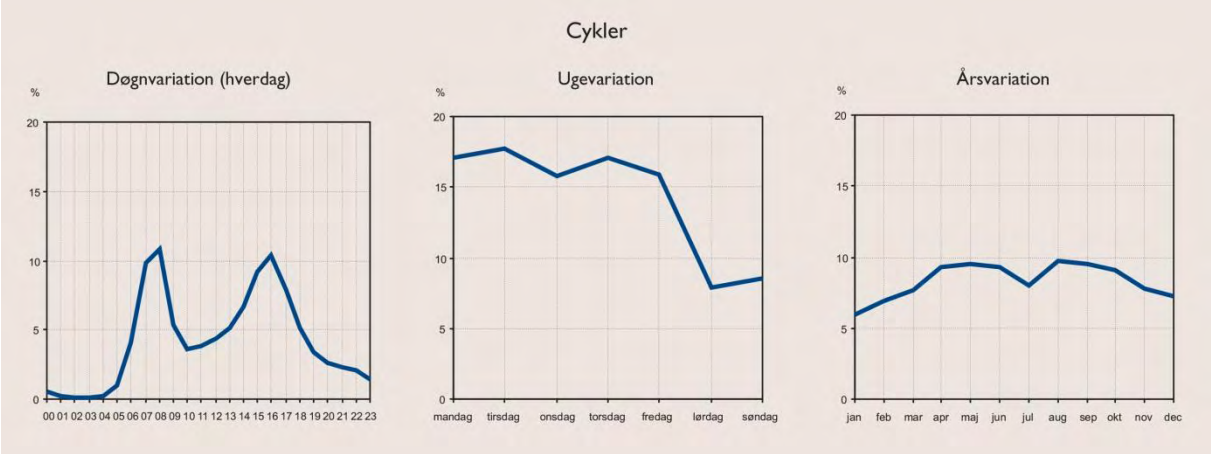
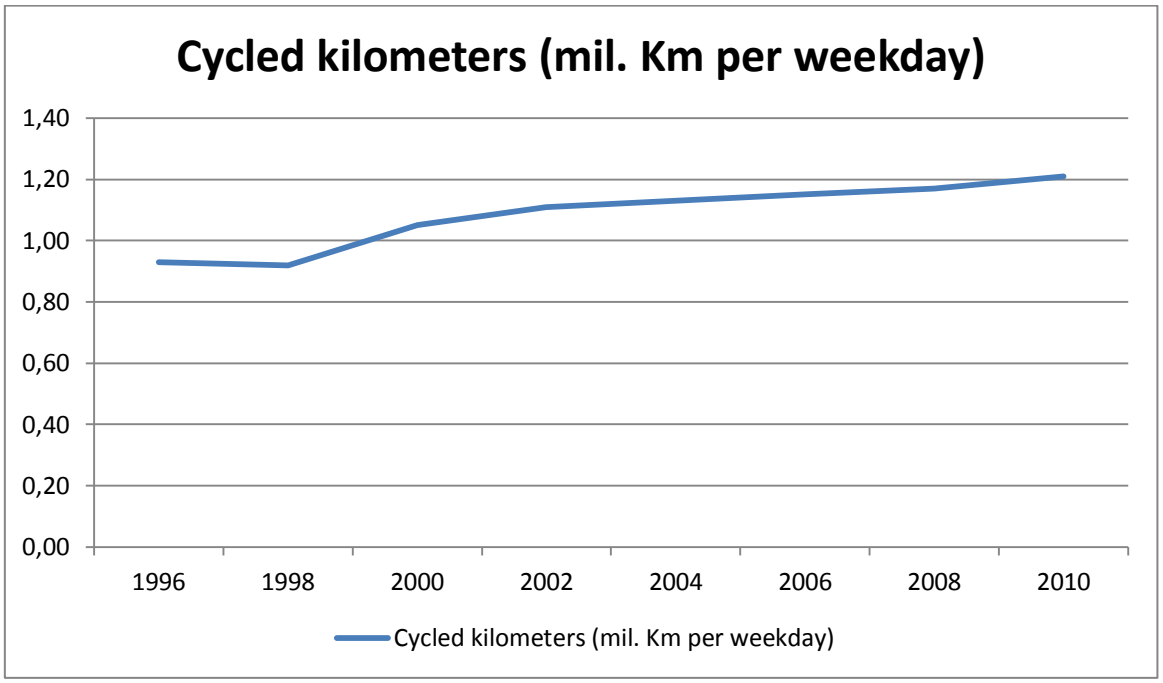


Image 10: Daily, weekly and yearly counting of cyclists (Københavns Kommune, 2006)

There has also been a growth in the kilometers cycled per day, since 1996 it has grown from 0.93 million kilometers per weekday to 1.21 in 2010.



Graph 10: Cycled kilometers (City of Copenhagen, 2010, own visualization)

In relation to motorized transportation, the inner city of Copenhagen has been drastically changing. The graph below shows that since 1975, which was a low point for cycling in the city center, the number of cyclists have quadrupled while there is a dropping trend of motorized vehicles entering the city center (Dutch Bicycle Council, 2010).

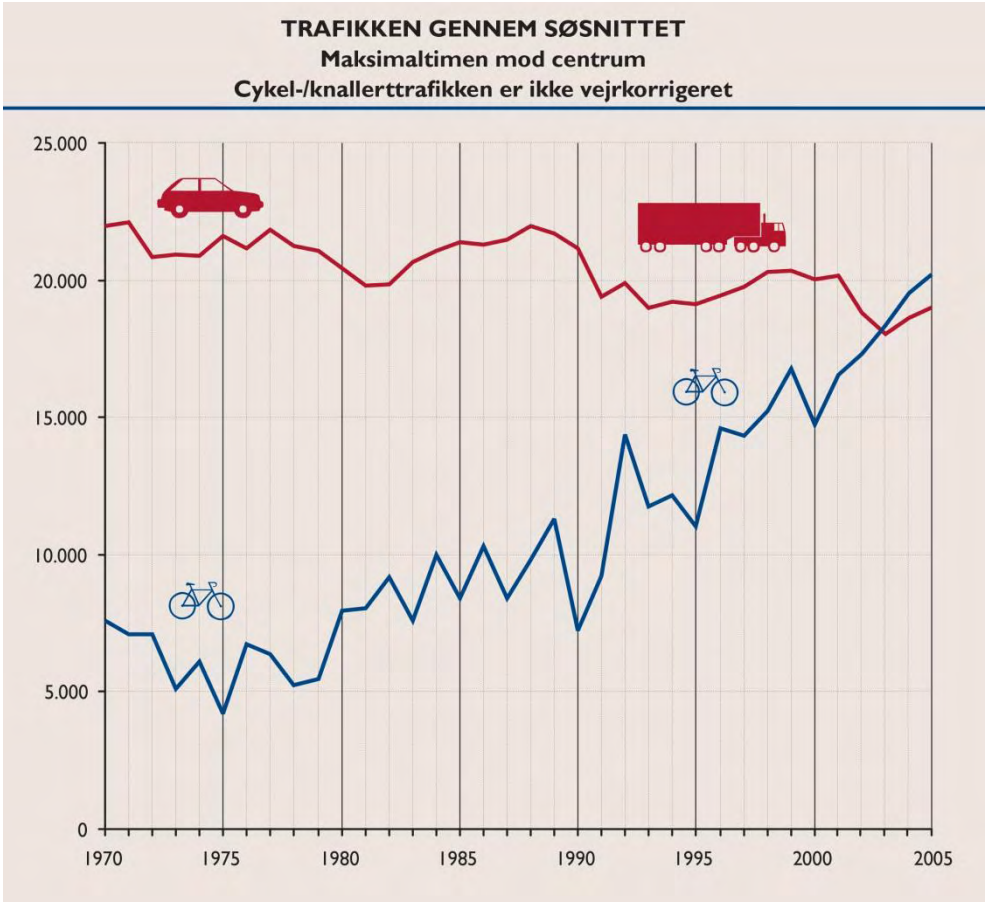
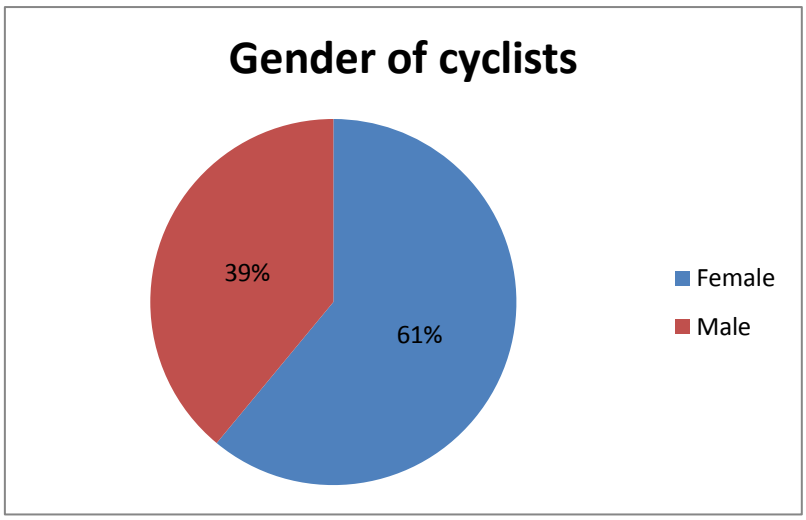


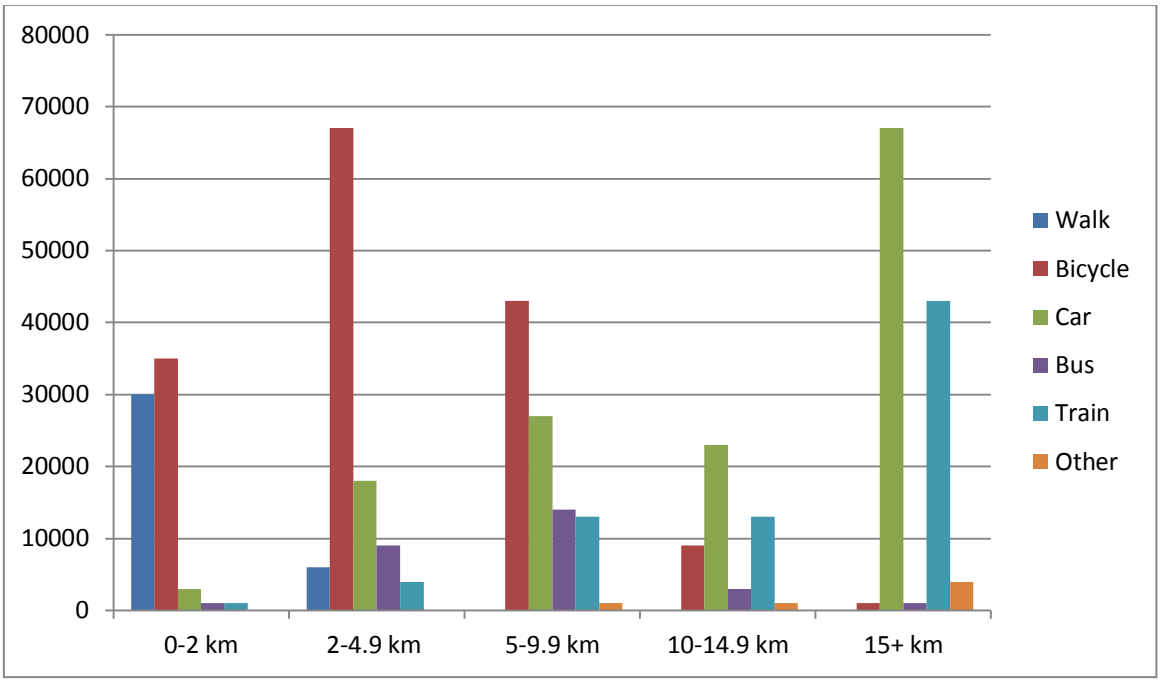
Image 11: Peak hour traffic of motorized transportation in marked red and cycling in blue (Københavns Kommune, 2006)

Women make up 61% of the cyclists, which is considered a very high proportion, especially since women are more sensitive to traffic stress than men and in many cities the men represent the higher share (Buehler & Pucher, 2012b).



Graph 11: Gender of cyclists (Buehler, 2012b; own visualization)

The following graph shows people who work or study in Copenhagen, divided according to the mode of transportation and the distance travelled. It shows that the bicycle share is dominant within the distances of up to 9.9 km.



Graph 12: Mode of commuting according to the distance (City of Copenhagen, 2010; own visualization)

4.5.2 Share of cycling Berlin

Again, as pointed out in the limitations of the study, various sources quote various numbers on the modal share of cyclists in Berlin. The numbers tend to move between 10-14%.The reason for the differences might be, that not all sources quote the exact year of data, which is in use. According to official publications in 2008, the modal share of cyclists was 13% (City of Berlin, 2008). When comparing the cyclist share of other German cities, Berlin is in the mid-range, as can be seen on the graph below.

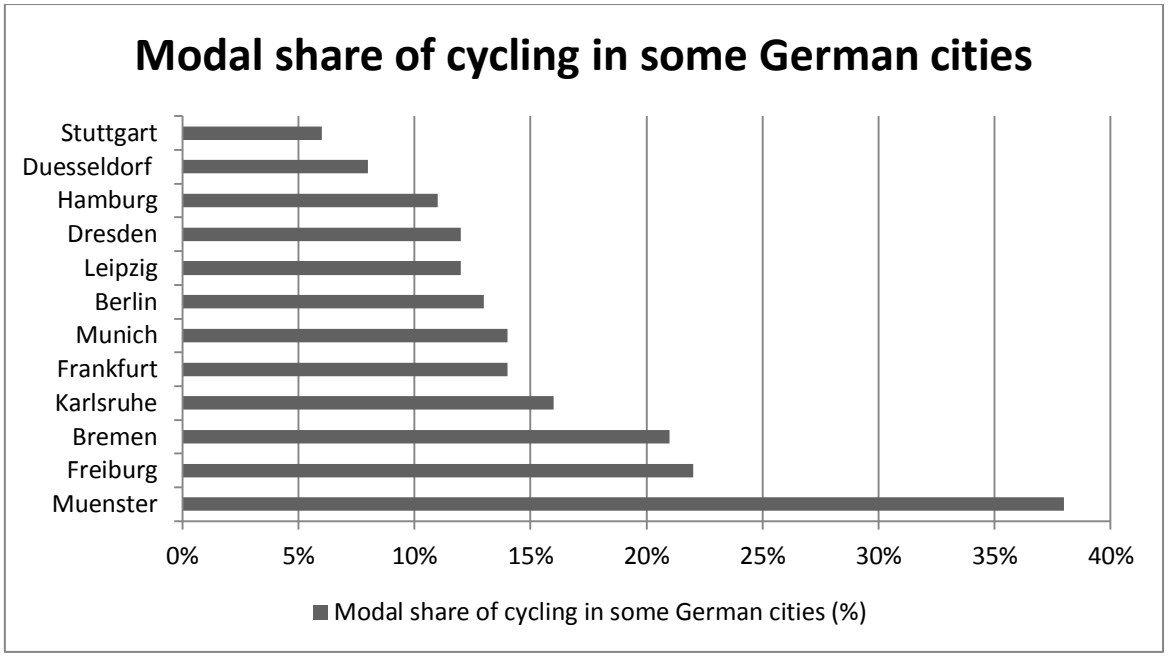
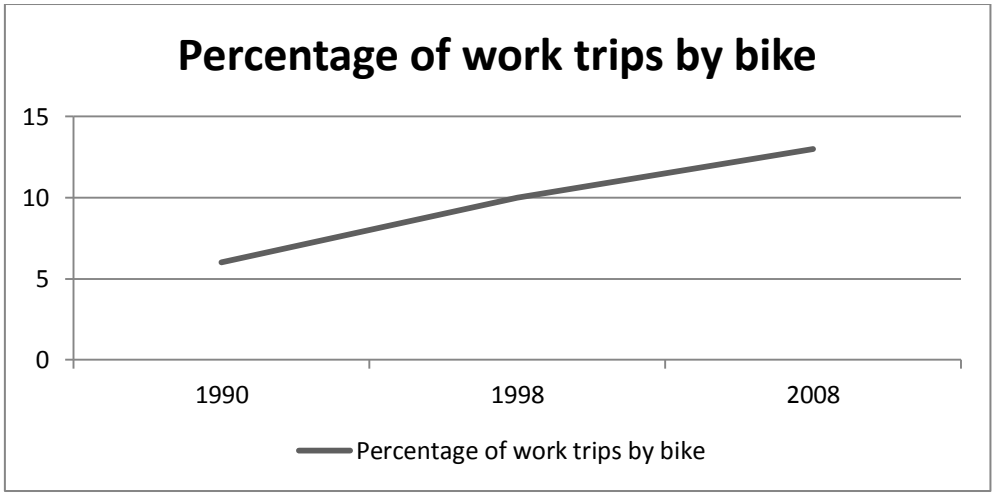


Image 12: Modal share of cycling in some German cities (Pucher & Buehler, 2012a; own visualization)

Over the last decades Berlin has seen a slow but steady growth in the cycling share, as can be seen on the graph below.



Graph 13: Percentage of work trips by bike in Berlin (City of Berlin, 2008; Buehler & Pucher, 2012a)

There are fairly big differences however in the cycling levels between the different districts. The image below shows that the cycling share varies from 6 to 21%. The middle shaded blue shows the percentage of cyclist on the pie charts. The tendency is that the districts closer to the inner city have an above average cycling level, while the outer districts have a lower level, with the exception of Pankow.

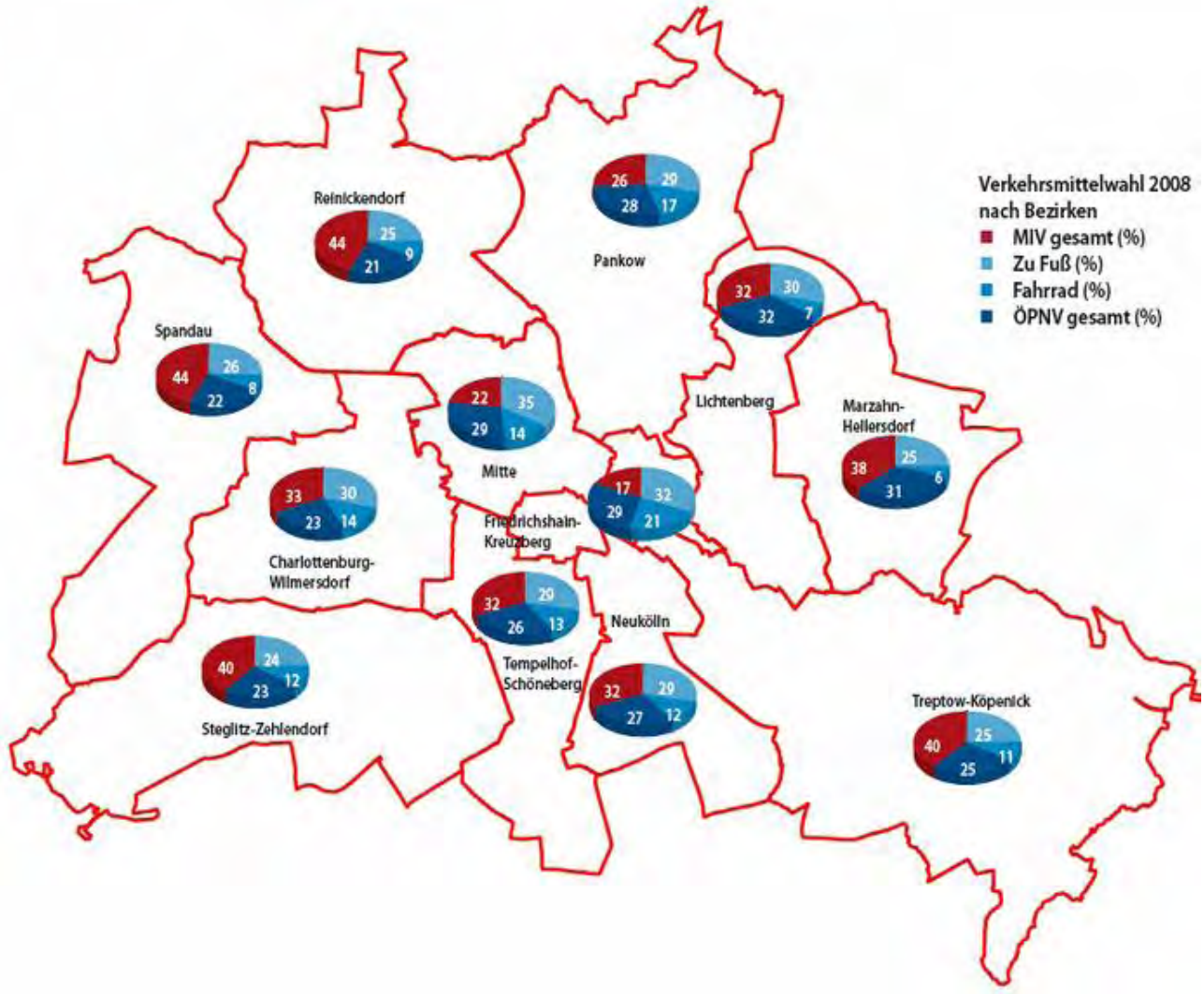
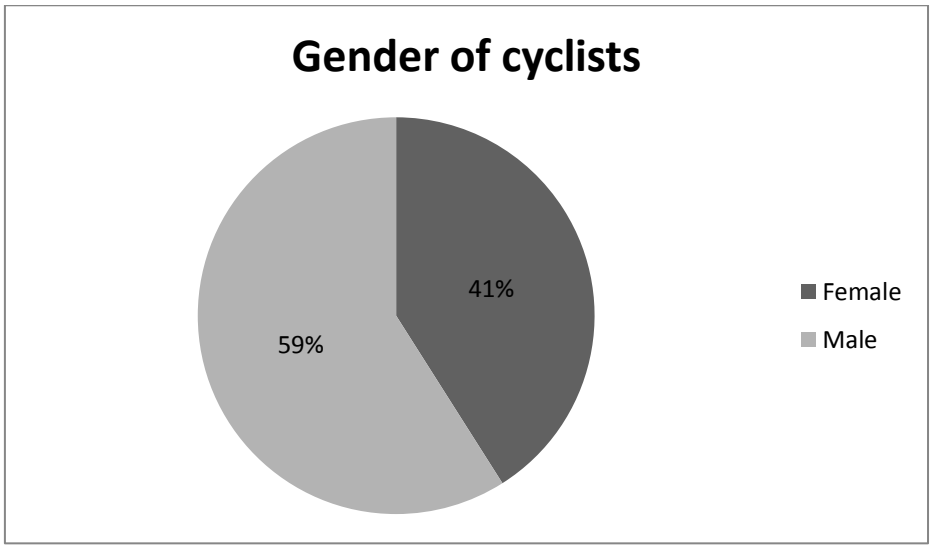


Image 13: Modal share of all trips in the municipalities of Berlin (City of Berlin, 2008)

Looking at the gender distribution of the cyclists in Berlin, in comparison to international figures Berlin is fairly equal with 41% of females cycling, but in comparison to Copenhagen it is still a low figure.



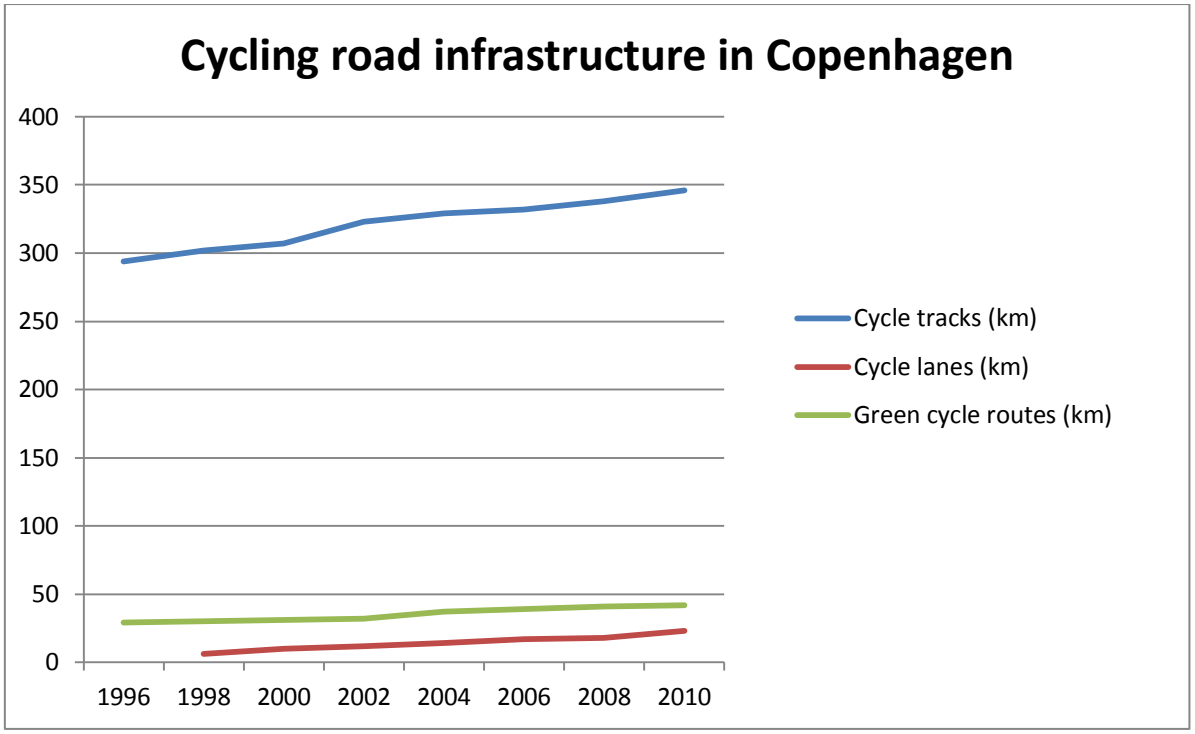
Graph 14: Gender of cyclists (Buehler & Pucher, 2012b, own visualization)

4.6 The types of cycling road infrastructure

The following chapter will have a look at what the existing road infrastructure is in the two case studies, based partially on the earlier chapter about road infrastructure options.

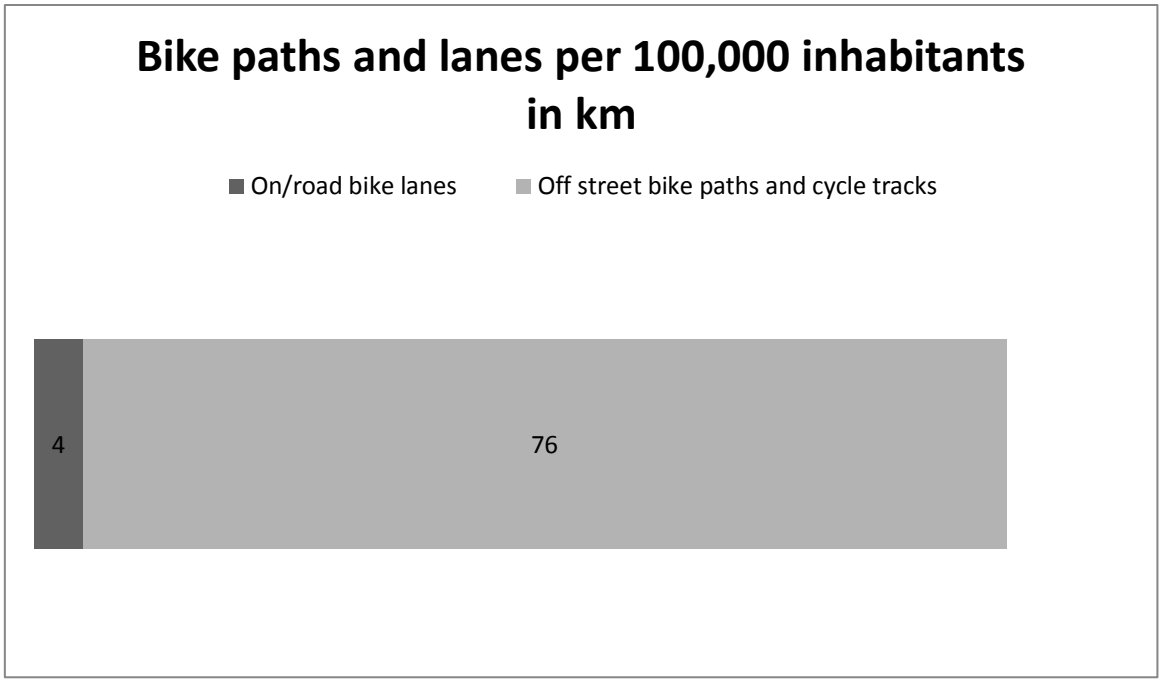
4.6.1 Infrastructure Copenhagen

Copenhagen has a tradition of separated cycle tracks, which originate from the 1930s. The cycle tracks are usually located on both sides of the street, on a separate level, between the road and sidewalk. The elevation of the cycle tracks is around 7-12 cm, while the width is between 2.2 and 2.5 meters, although on commuter routes with high traffic they can be as wide as three meters. Copenhagen has the largest network of cycle tracks globally with the aforementioned characteristics (Buehler & Pucher, 2012b). The following graph shows the development of the different infrastructure typologies over recent years. Cycle tracks make up an overwhelming part of the road infrastructure with 346 km length in 2010. In the same year there were 23 km of cycle lanes and 42 km of green cycle routes.



Graph 15: Cycling road infrastructure in Copenhagen (City of Copenhagen, 2010)

According to Niels Jensen, planner for the city of Copenhagen the politically approved plans are focused on three typologies of infrastructure: cycle tracks along major roads, green cycle routes and cycle super highways. When categorizing the cycle tracks into off-street bike paths and cycle tracks per 100,000 inhabitants and on-road bike lanes per 100,000 inhabitants, it is clear that an overwhelming amount of the infrastructure in Copenhagen is off street bike paths, the ratio being 1:19 in favour of off road infrastructure.



Graph 16: Bike paths and lanes per 100,000 inhabitants (Buehler & Pucher, 2012b; own visualization)

The cycle tracks are focused on the main arterial roads of the city, connecting the city centre directly with the peripheral urban structures. The advantages are that the routes for cyclists are short, because they are direct and they can have long green phases, which are synchronized with the motorized traffic. On the downside cycling happens in proximity to noise and pollution (Dutch Bicycle Council, 2010). The map on the right shows the so called regional roads in red, distribution streets in dark blue and town streets in light blue (direct translations). The arterial road structure of the city is clearly recognizable on the map. The map does not include any cycling infrastructure.

Image 14: Road structure of Copenhagen (Københavns Kommune, 2006)

Since the developments are focused on arterial roads, connecting routes in low-traffic residential neighbourhoods have not been developed (Buehler & Pucher, 2012b). To some extent there has been a shift of focus on low traffic roads, Nørrebrogade being the first instance. With the closure for motor vehicles, a former arterial road has been developed into a low-traffic road (Dutch Bicycle Council, 2010).

The arterial road structure of Copenhagen can also be recognized when looking at the traffic flows. The map on the right shows the number of cyclists and mopeds counted on a workday between 6 in the morning until 6 in the evening. The thickness of the line represents the intensity, as noted on the map.

When overlapping the two maps, the one showing the road typology and the cycle traffic, it is clear that most cyclist commuting is along the main arterial roads. The following map shows the cycling intensity overlaid on the map of the road typology.

Image 16: Vehicle traffic flow of Copenhagen (Københavns Kommune, 2006)

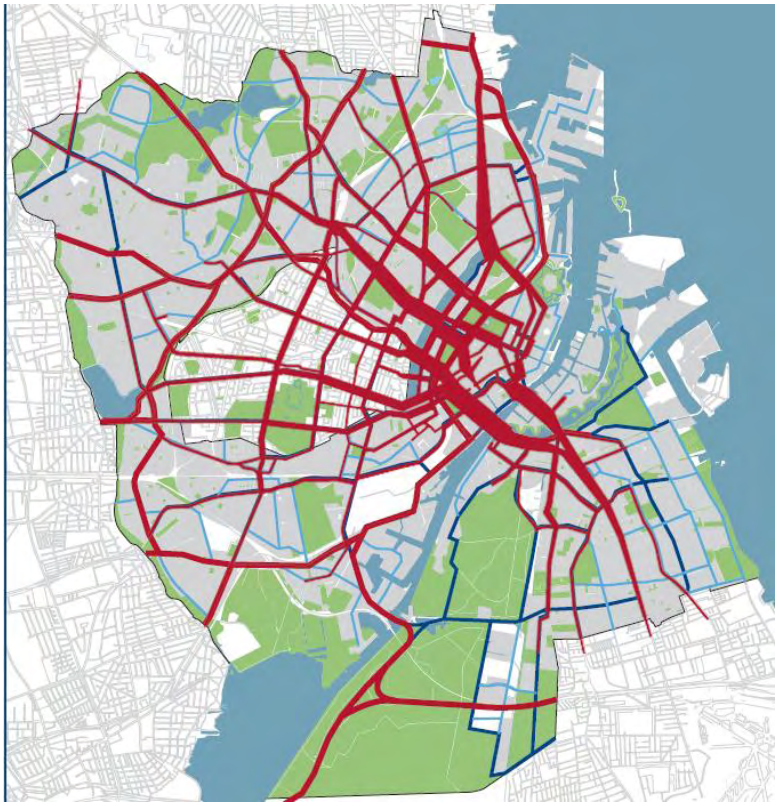


Image 15: Overlapping the trafficflow over the street network (Københavns Kommune, 2006)

The map on the right shows the cycle tracks in Copenhagen. It can be recognized that the mesh of the network is smaller in the center than it is in the peripheral areas.

Image 17: Cycle tracks in Copenhagen (Københavnerkortet Københavns Kommune, 2013)

The map below shows some examples of the cycle track width at specific locations. It is interesting to see that the historic city center does not have any cycle tracks. The cycle tracks are marked purple on the image below.

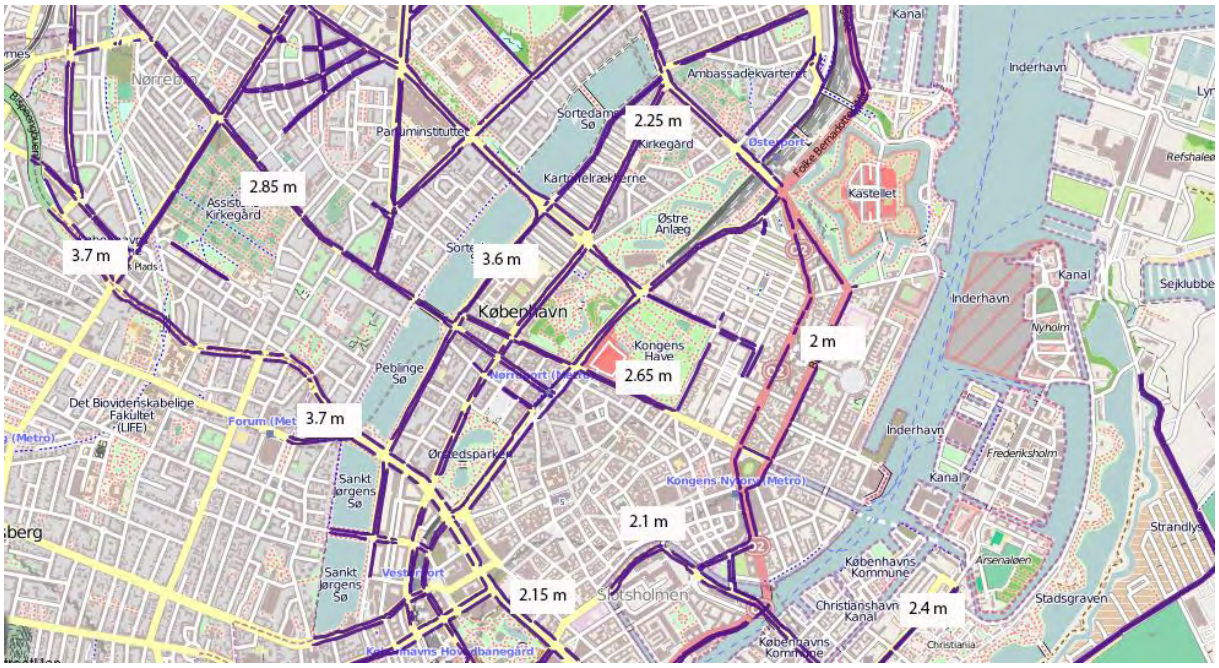


Image 18: Selected cycle track widths (Geocommons, 2006)

Copenhagen has multiple green cycle routes, which can be seen on the following map. The routes are planned in a fashion to avoid heavy traffic and run mainly through recreational areas. The aim is to supplement the existing infrastructure, not replace it and to ease the cycle traffic on the existing roads. The routes have a length of 43 km, but further 67 km are planned, as soon as the funding is available. In total there should be 22 green cycle routes, on average 5 km long each (Dutch Bicycle Council, 2010). Since the routes are newly created, allowing for shortcuts in an already established infrastructure, they offer in some cases a shorter travel time for cyclists (City of Copenhagen, 2013a).

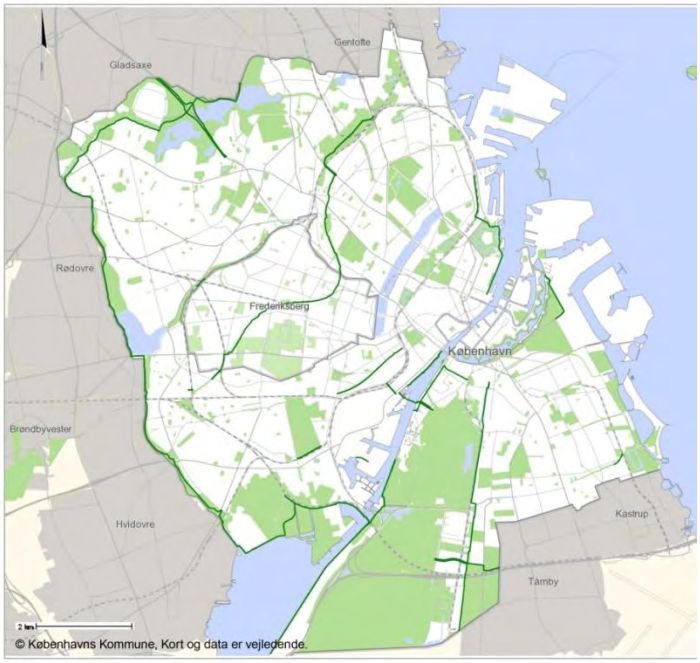
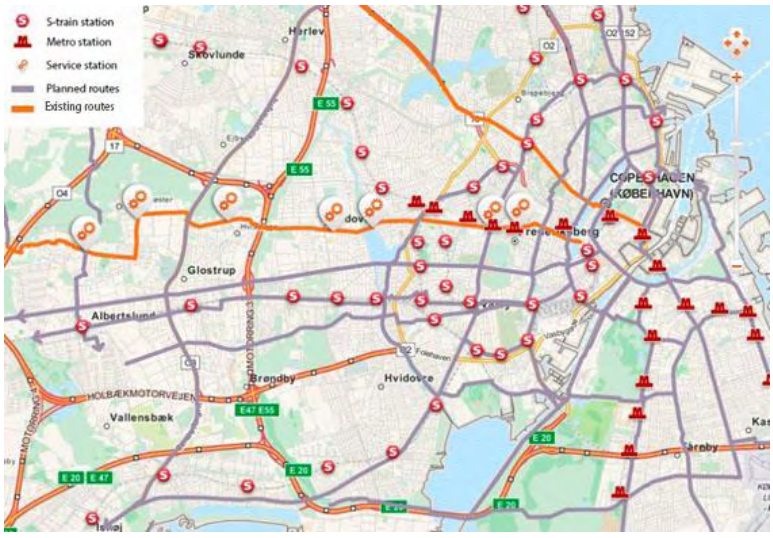


Image 19: Green cycle routes in Copenhagen (Københavnerkortet Københavns Kommune, 2013)

Image 20: A green cycle route in Copenhagen (own image)

Cycle super highways have been introduced in the greater area of Copenhagen. The aim is to create routes, which connect homes with public transportation, educational facilities and workplaces. The route should offer a direct connection with as few obstacles as possible, which is also why the "green waves" were introduced, which means that the traffic lights are catered towards an average cycling speed (20 km/h), so that cyclists aren't delayed at traffic lights. The map on the right shows the planned (grey) and already existing (orange) cycle super highways. The planned routes reach far out of the city creating regional connections. The close-up below shows the routes more in detail. The first super highway was also equipped with so called "service station", which means that air pumps are available for cyclists. The routes run along main public transportation lines, both the stations of the S-train and the metro (Cykelsuperstier, 2013).

Image 21: Planned Cycle SuperHighways (Cykelsuperstier, 2013)



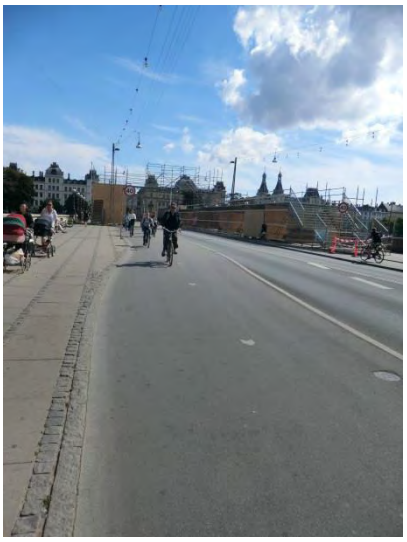


Image 22: Existing and planned Cycle Super Highways (Cykelsuperstier, 2013) and a section of a Cycle Super Highway (Own image)

Winter maintenance has a high priority in Copenhagen, the map on the right shows, which cycle tracks and lanes are subject to winter maintenance. The policy of the city is to clear snow from cycling tracks before car lanes, except for four main roads. 80% of cyclists in Copenhagen cycle throughout January, which is probably due to this policy (Denmark.dk, 2013b).

Image 23: Routes of winter maintenance (Københavnerkortet Københavns Kommun, 2013)

According to Niels Jensen, the areas which need most development are establishing a few cycle tracks along major roads, improving existing cycle tracks on the busiest roads, the expansion of green cycle routes and cycle super highways.

4.6.1.1 Green waves and lights

In Copenhagen so called Green waves were developed, which means that the traffic lights on specific roads are synchronized for cyclists to provide them with consecutive green lights, making travel times shorter. The lights are synchronized so that at an average speed of 20 km/h cyclists do not have to stop at lights (Denmark.dk, 2013b). In 2010 there were four green waves along four arterial roads (Buehler & Pucher, 2012b). The image on the right shows the speed development before and after the green wave was introduced. The example is taken from Norrebrogade, and shows a clear stabilization of speed for cyclists.

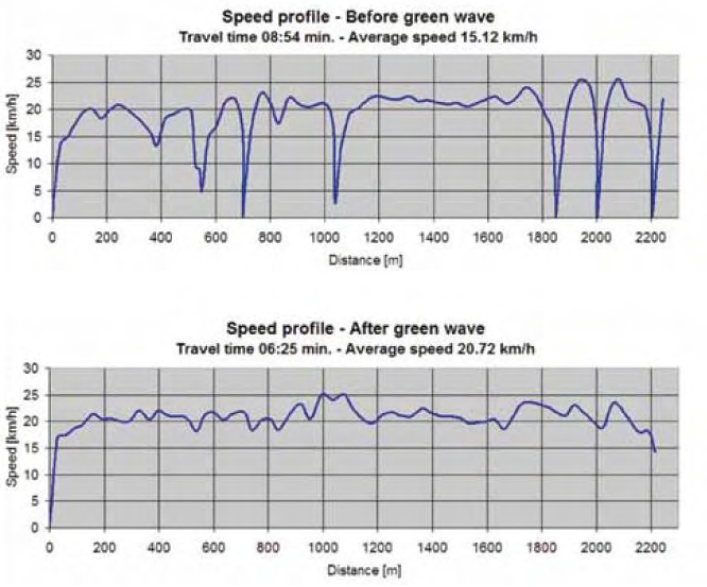


Image 24: Speed profile before and after green wave (Andersen et al., 2012)

4.6.1.2 Intersection design

As already mentioned, intersection design is crucial in cycling safety. When making a turn in Copenhagen, the Danish traffic code requires that cyclists have to proceed to the opposite corner before turning left (Andersen et al., 2012), as can been seen on the illustration on the right. Generally for the city there is a rule that cars are not allowed to park in a 10 meter zone of intersections in order to create a better visibility of cyclists. In case of a signalized intersection there should be no cars in a 20-30 m range of the intersection, for the same reason (Andersen et al., 2012).

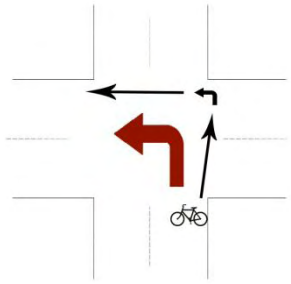


Image 25: Left turn in Copenhagen (own visualization)

Cycle tracks are typically marked in blue at intersections since the 90's with white bicycle symbols. The experience with these markings has been rather positive and studies have shown increased safety (Dutch Bicycle Council, 2010). There should be preferably a blue marking in only one direction of an intersection, although Copenhagen has been implementing up to two marked crossings, after individual consideration to road safety (Andersen et al., 2012). All together 117 intersections are designed with advanced stop lanes and traffic signal priority. These advanced stop lanes are on the right side of the road, having the width of the cycle track, but not stretching across the entire road (Buehler & Pucher, 2012b). If the cyclists are positioned closer to the intersection than cars, their visibility will be better, thus causing less accidents with cars turning right (Dutch Bicycle Council, 2010). The traffic lanes should be set back by 5 meters in comparison to the cyclist stop line. The cycle tracks are converted a few meters before the intersection into cycle lanes, which after crossing the road are turned back into cycle tracks (Dutch Bicycle Council, 2007). Ideally a cycle track will convert to a cycle lane leading up to the stop line, continuing as a blue marked lane and then converting back to a cycle track after the intersection. Cycle tracks tend to move conflicts from the road to intersections, which make careful considerations in each case necessary (Andersen et al., 2012).

Image 26: Blue marking at intersection (own image)

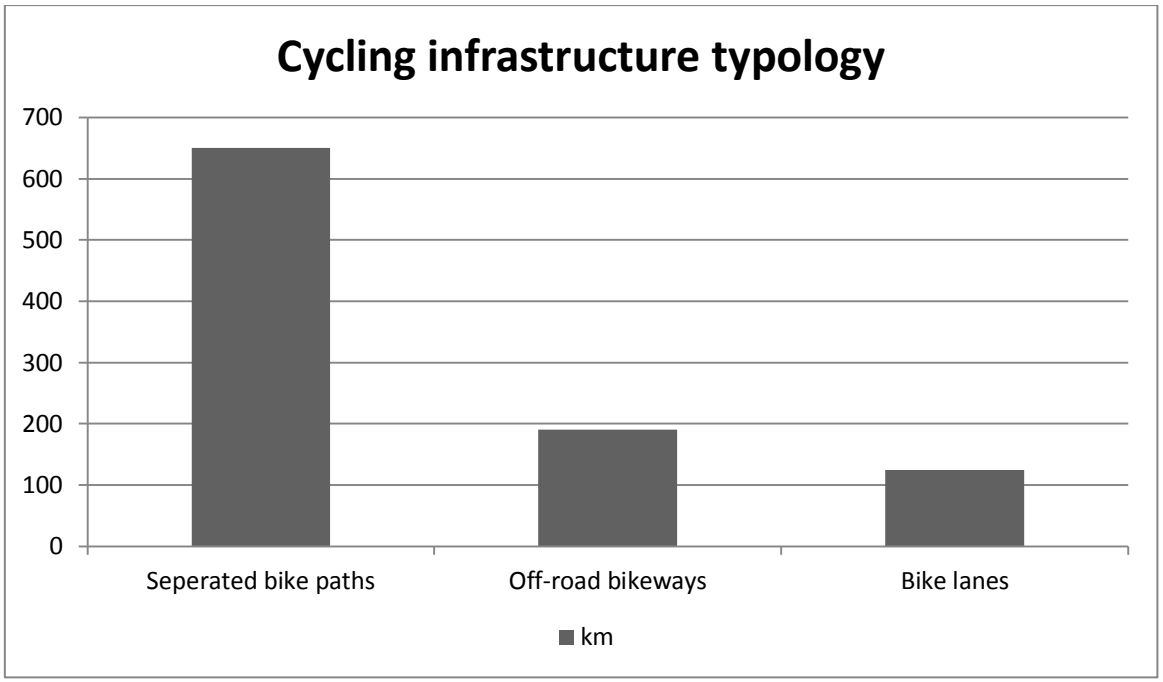
4.6.1.3 Bicycle bridges

In 2006 a 150 m long and 5.5 m wide bridge was opened, which is only accessible for cyclists and pedestrians, creating a better link between two districts of the city. In 2009, 8,500 daily users were counted (Dutch Bicycle Council, 2010). Three further bridges are planned, one of them, which is already under construction, to create a better connection throughout the city (City of Copenhagen, 2013c).

Image 27: Location of the new bridges (Politiken, 2012)

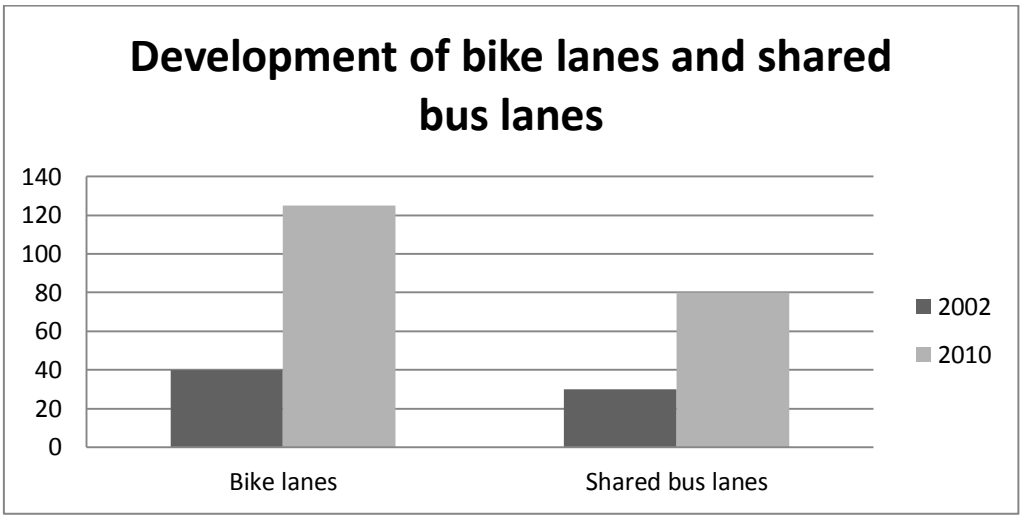
4.6.2 Infrastructure Berlin

A big part of the cycling infrastructure of Berlin consists of, similar to Copenhagen separate bike paths along roads, off road bikeways through parks and forests and traffic calmed neighbourhoods.



Graph 17: Cycling infrastructure typology (Buehler & Pucher, 2012b; own visualization)

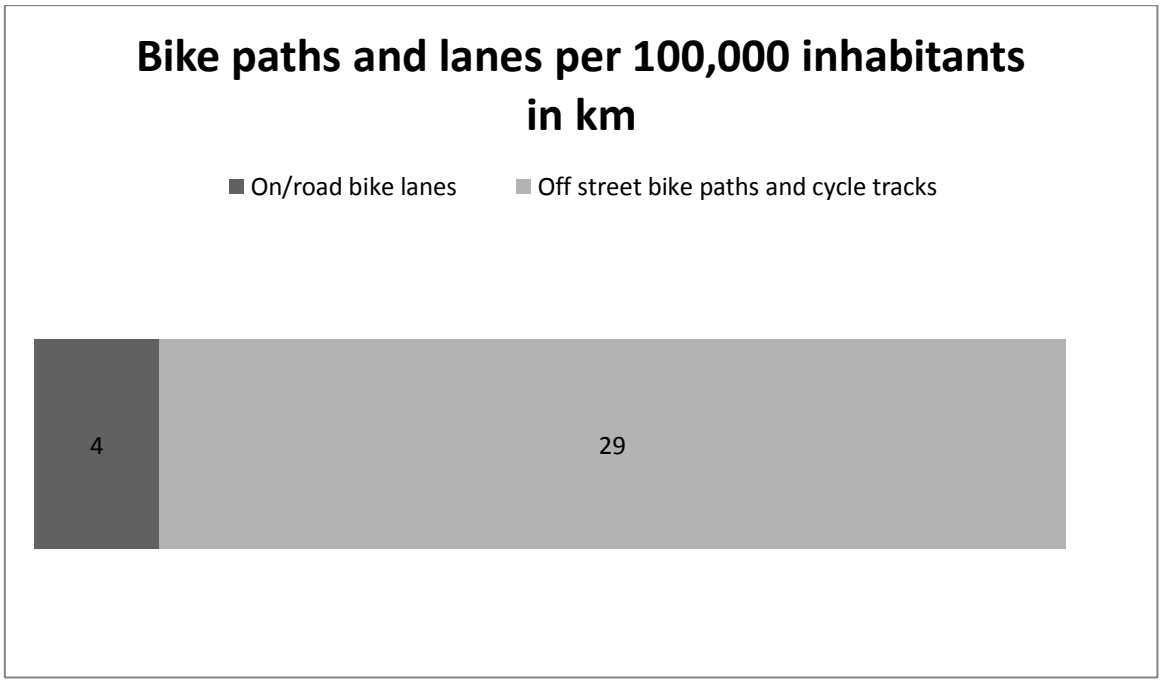
Between 2002 and 2010 Berlin has focused on the development of bike lanes and shared bus lanes. The length of bike lanes grew from 40 to 125 km while the shared bus lanes grew from 30 to 80 km. This increase in bike lanes instead of separated bike paths can be connected with the lower construction costs (Buehler & Pucher, 2012b).



Graph 18: Development of bike lanes and shared bus lanes (Buehler & Pucher, 2012b; own visualization)

The issue with the shared bus lanes is that they usually do not meet the norm width for co-use of bicycle, which is 4.75 m. In specific parts the width is below 3.5 m, which often does not allow for the safety distance for overtaking (Horn, 2009).

When looking at the on and off road cycling infrastructure of Berlin there is a certain extent of similarity to the graph of Copenhagen. While there is a big emphasis on off road infrastructure, the ration of off and on road infrastructure is 1:19 in Copenhagen, while in the case of Berlin this is only 1:7.25. While in Copenhagen there is 80 km of cycle facilities per 100,000 inhabitants in Berlin this is only 33km.



Graph 19: Bike paths and lanes per 100,000 inhabitants (Buehler & Pucher, 2012b; own visualization)

While Berlin statistically is doing well in an international comparison, the issue is that a lot of the existing infrastructure does not live up to the minimum requirements. While a cycle track has to be at least 1.5 meter wide, there are examples for cycling tracks, which are less than one meter wide (Tagesspiegel, 2009). Furthermore there are also issues considering the surface and the intersection design of existing infrastructure (Rennrad-Nordgruppe Berlin, 2013). The qualitative deficiency of the

Image 28: Example for uneven pavement on cycle track (own image)

existing cycling infrastructure clearly showed in the survey carried out in this research. Out of those, who answered the open question, 25% of the participants mentioned issues about the quality of cycling tracks and lanes. Most often the problems were centred around the uneven surfaces, bad material choice, insufficient width and missing markings. While there are qualitative regulations for the newly built cycling infrastructure there is no qualitative information available on the existing cycling infrastructure (for instance including width).

There is an online tool provided by the city, in order to see what type of cycling infrastructure is available on which roads. The qualities however are limited for users, the following image showing the cycling network of Berlin. Since the plan is rather large, a close-up of the network was also included for a better understanding.

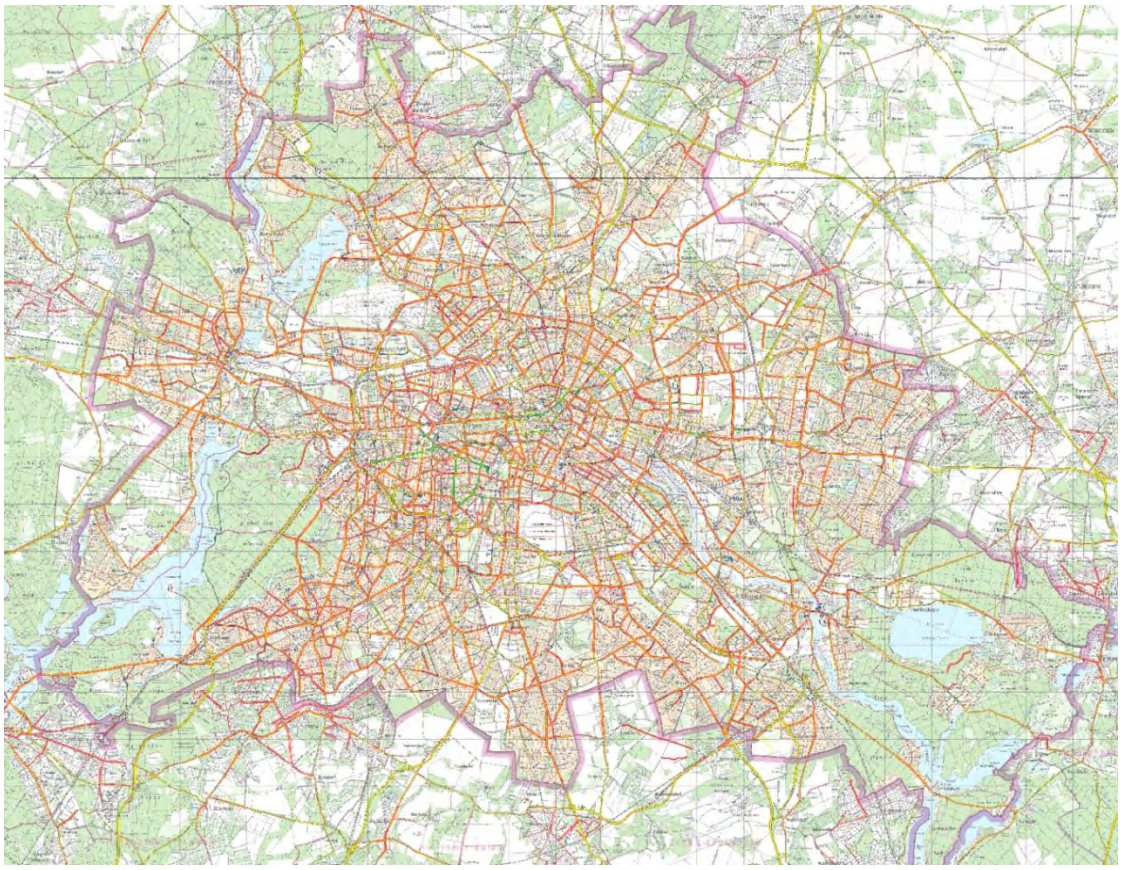


Image 29: Cycling infrastructure in Berlin (FIS-Broker, 2013)

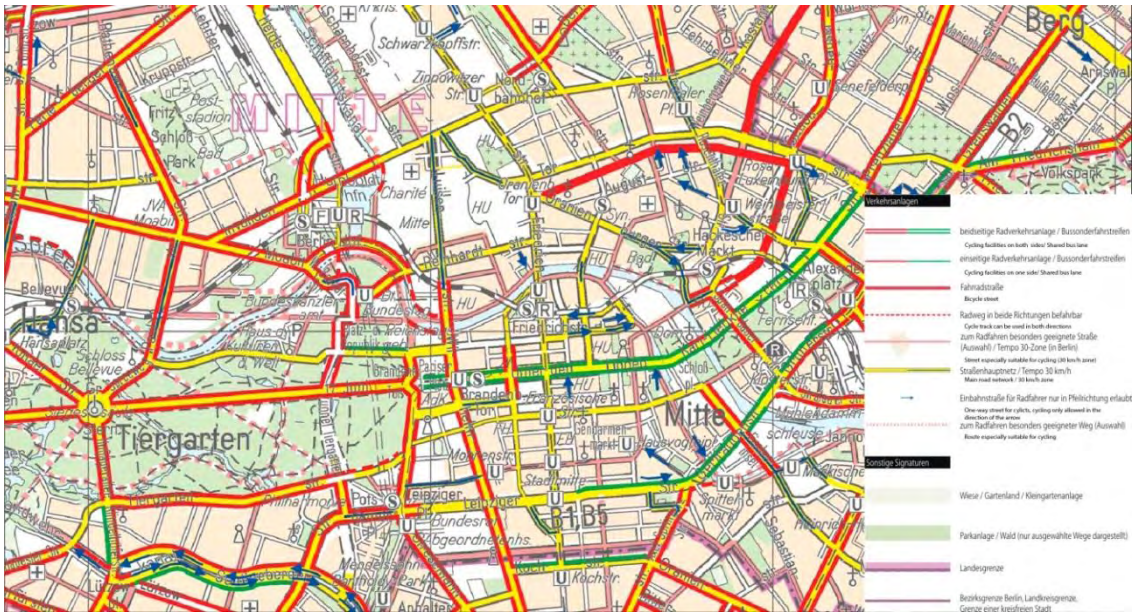


Image 30: Cycling infrastructure in Berlin detailed view (FIS-Broker, 2013)

On the map there is no differentiation between cycle tracks and cycle lanes. There is no qualitative information available on the map considering specifications, such as width, protection by a parking lane, etc.

On the one hand the international literature tends to describe Berlin as a good example for other cities to follow; especially because the hard numbers such as track length, lane length, etc. show that there is a highly developed cycling infrastructure. On the other hand the survey carried out during this research showed that there are big issues with the quality of the facilities. Of those who answered the open question, 2,5% specifically wished for better surface materials, 4,2% wanted wider cycle facilities and 4,7% wanted better maintenance of the existing cycling infrastructure.

Image 31: Cycle lane in Berlin abruptly ending on a sidewalk (own image)

When looking at the surface material used for cycling infrastructure it becomes clear that there are many variations throughout the city. The following images show three examples of surface materials. These materials deteriorate faster than asphalt and many of these cycle tracks have an uneven surface due to the stones slightly moving.

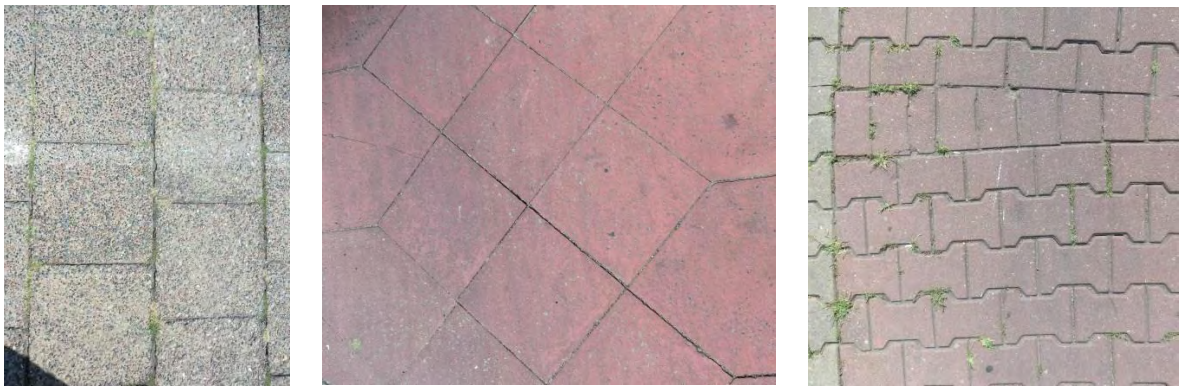
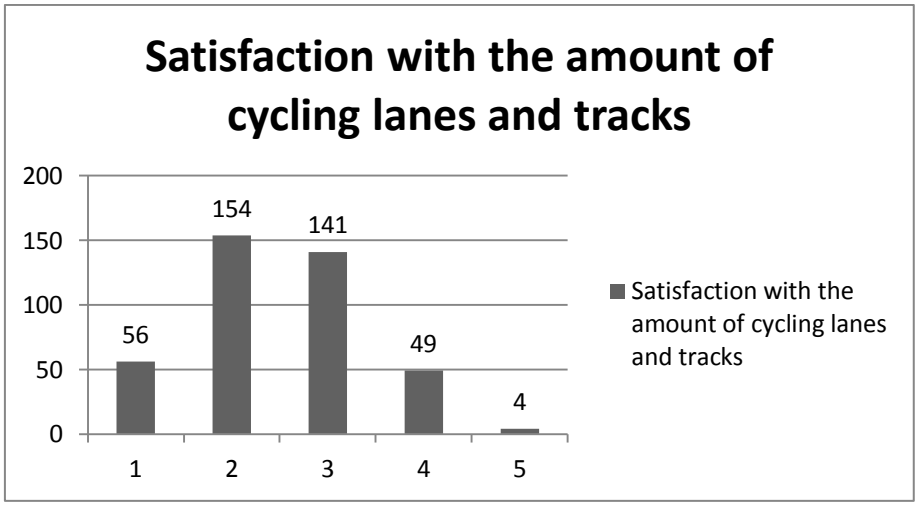
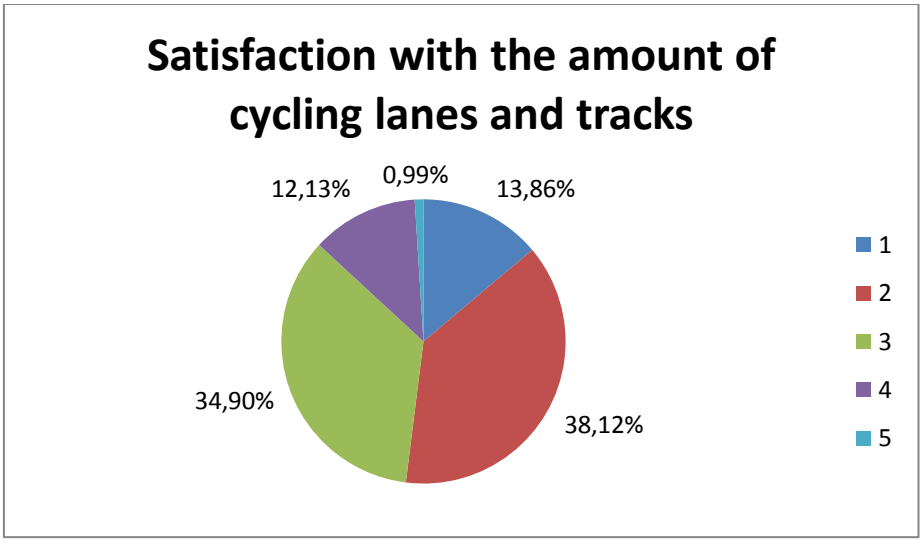


Image 32: Different surface materials used in Berlin (Own images)

The average grade given in the survey for the satisfaction with the amount of cycling lanes and tracks was 2.48, on a scale of 1 to 5, 1 being the lowest and 5 being the highest rating. Around 52% of the participants answered with the two lowest rating categories.

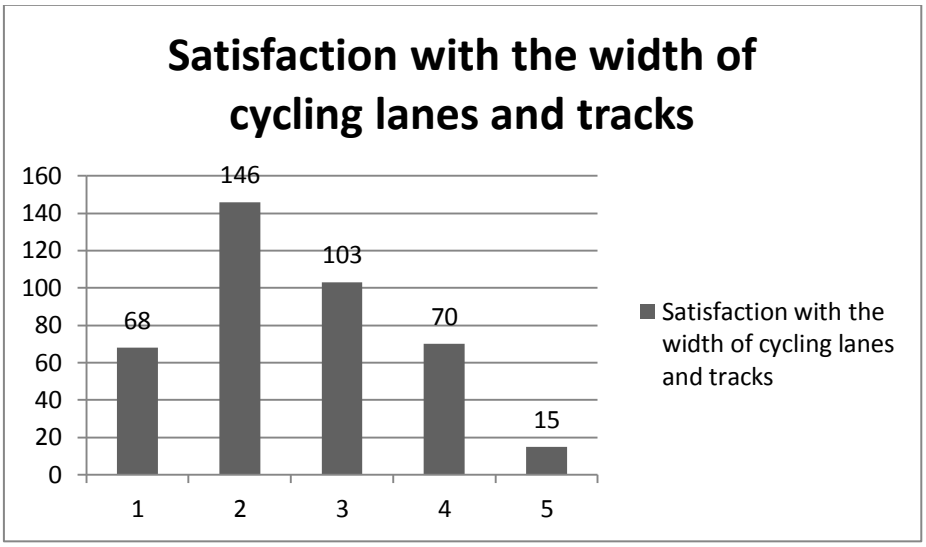


Graph 20: Satisfaction with the amount of cycling lanes and tracks (Own survey)

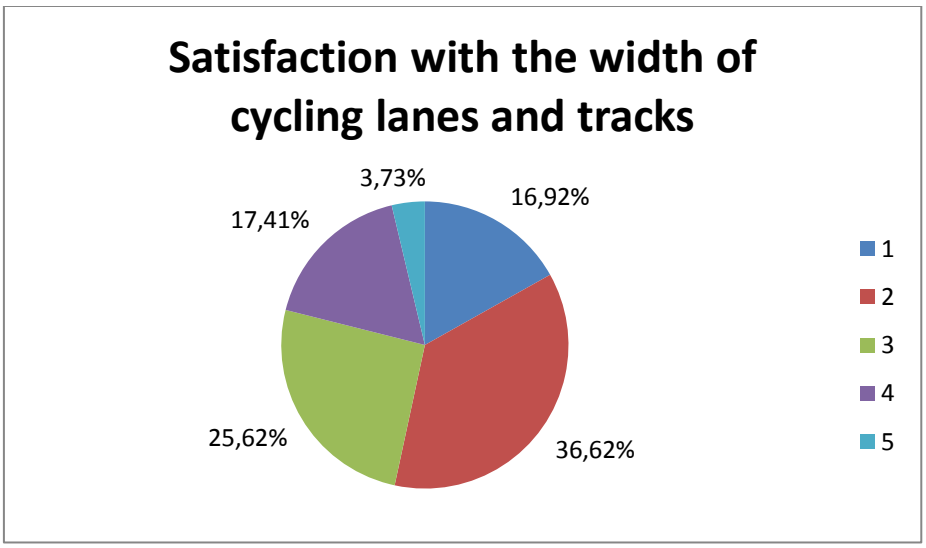


Graph 21: Satisfaction with the amount of cycling lanes and tracks (Own survey)

The average grade given in the survey for the satisfaction with the width of cycling lanes and tracks was 2.55. The two lowest categories, namely one and two, with 214 answers exceed the intermediate and two highest categories with 188 answers.

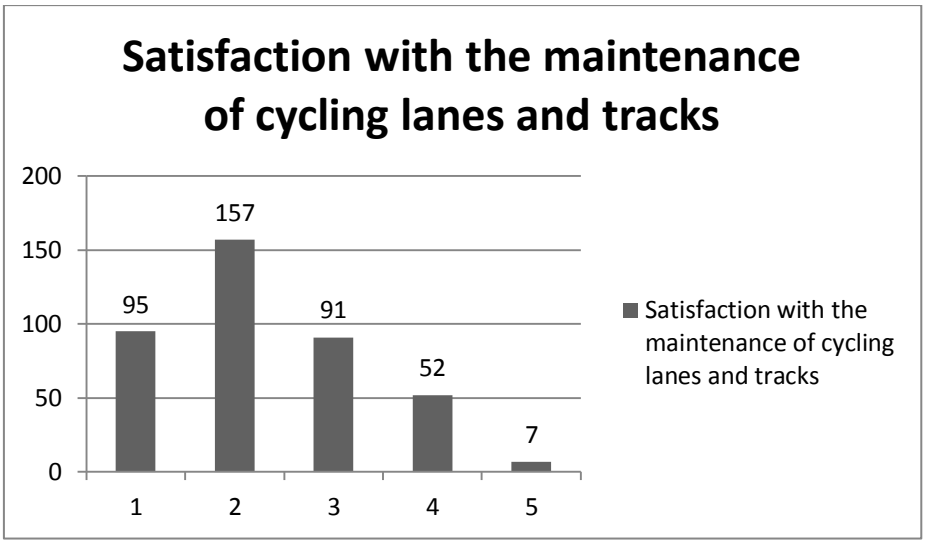


Graph 22: Satisfaction with the width of cycling lanes and tracks (Own survey)

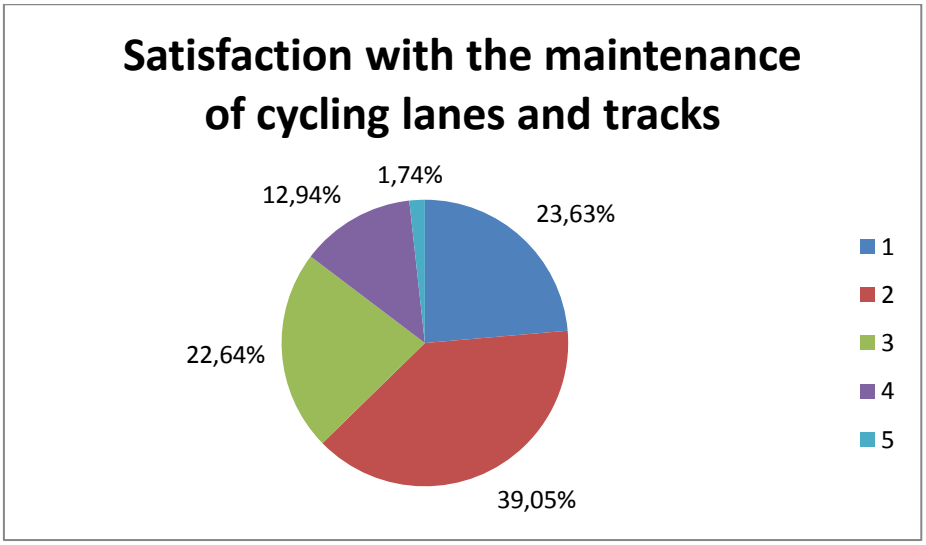


Graph 23: Satisfaction with the width of cycling lanes and tracks (Own survey)

The average grade given in the survey for the maintenance of cycling lanes and tracks was 2.3. The two lowest ratings were chosen by around 63%.

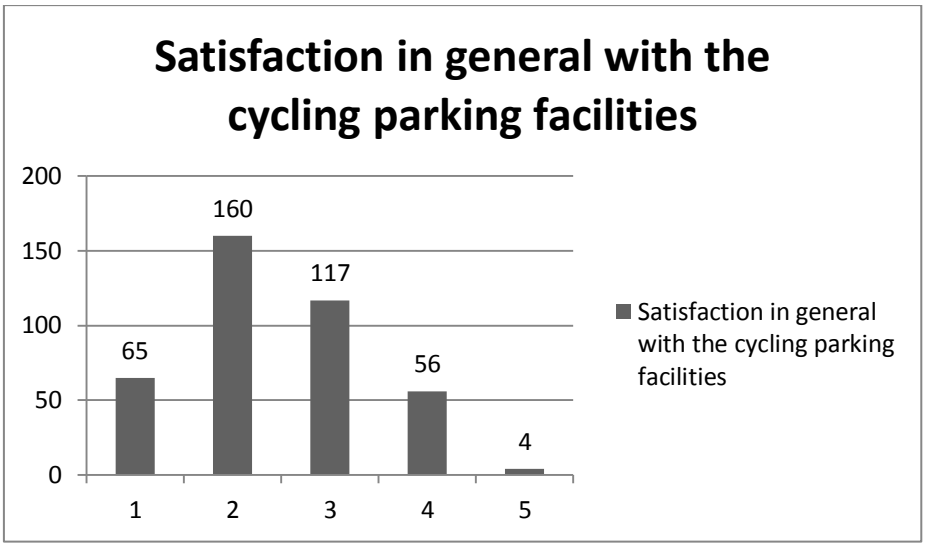


Graph 24: Satisfaction with the maintenance of cycling lanes and tracks (Own survey)

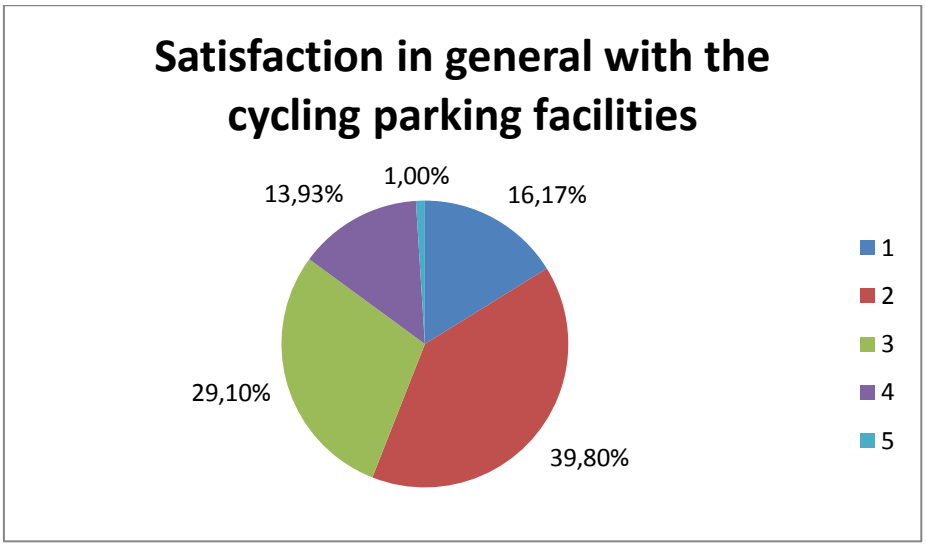


Graph 25: Satisfaction with the maintenance of cycling lanes and tracks (Own survey)

The average grade given in the survey for the satisfaction with cycling parking facilities was 2.44. Around 56% of the participants choose the two lowest ratings.

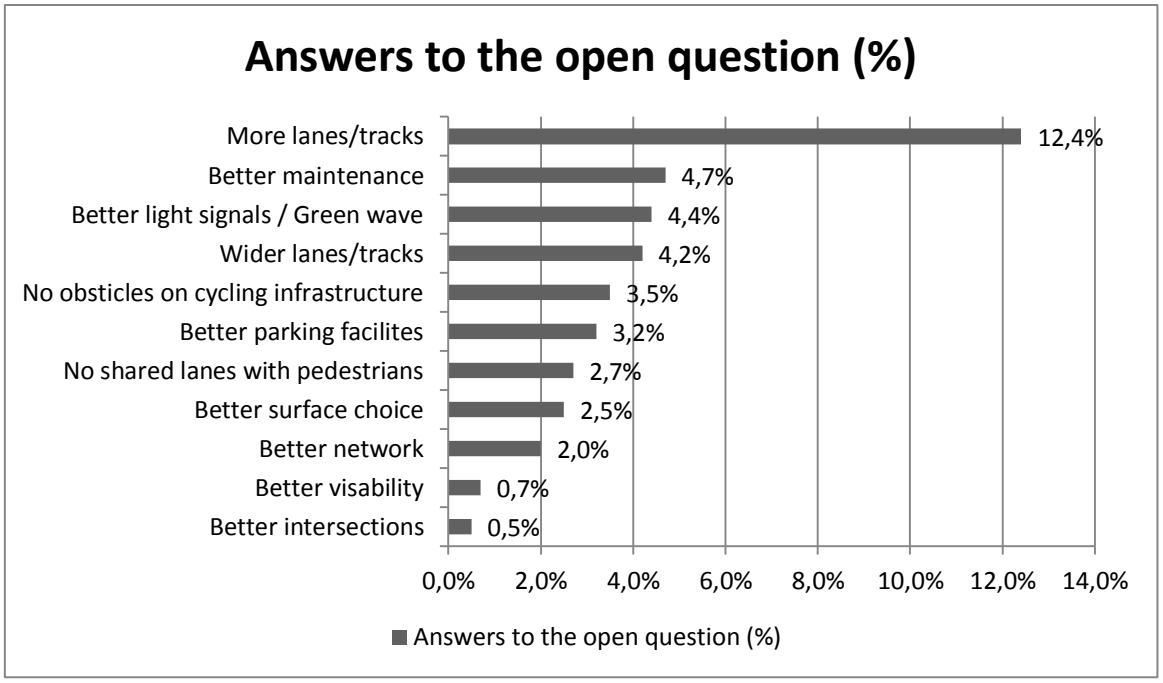


Graph 26: Satisfaction in general with the cycling parking facilities (Own survey)



Graph 27: Satisfaction in general with the cycling parking facilities (Own survey)

None of the answers for these four aspects reached the level of 3. The maintenance is being rated the worst, with the parking facilities following. The following open question was posed in my survey: "What would make you cycle more? Any suggestions are welcome!". The answers were filtered for specific aspects, which are represented in the following graph.



Graph 28: Outcome of the open question of the survey (Own survey)

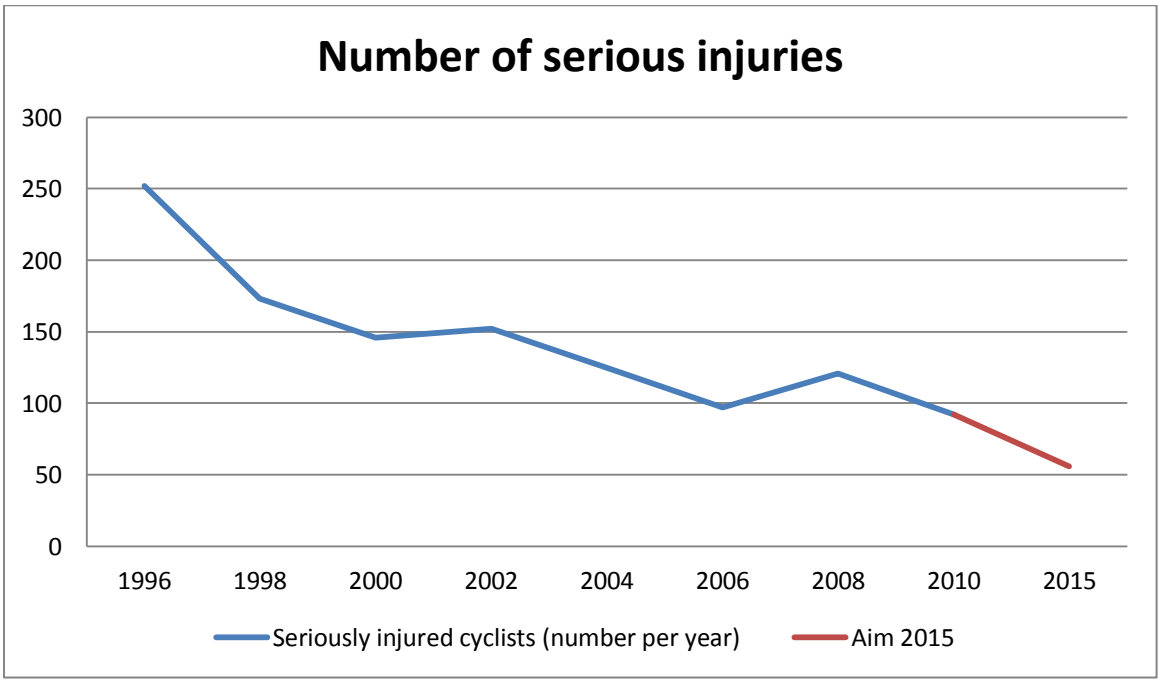
Due to the nature of the question, not all answers could be categorized. Many answers given were rather general, for instance “Better cycle lanes”, which didn’t fit in specific categories. The answer, which was given most, is that the participants wished for more cycle lanes or tracks (in general cycling infrastructure).

4.7 Safety

In many European countries there is a common understanding that there is a need for separation of cyclists and heavy traffic in order to create a safe cycling environment. Both in Germany and Denmark they recommend increasing separation of traffic with increasing traffic volume and speed (Furth, 2012). The effort to create a safe cycling environment is a possible reason for a higher level of cycling among all groups in both Germany and Denmark (Buehler & Pucher, 2012a). Part of the strategy to create safer traffic environments is a general traffic calming policy, which will be discussed later on (Furth, 2012).

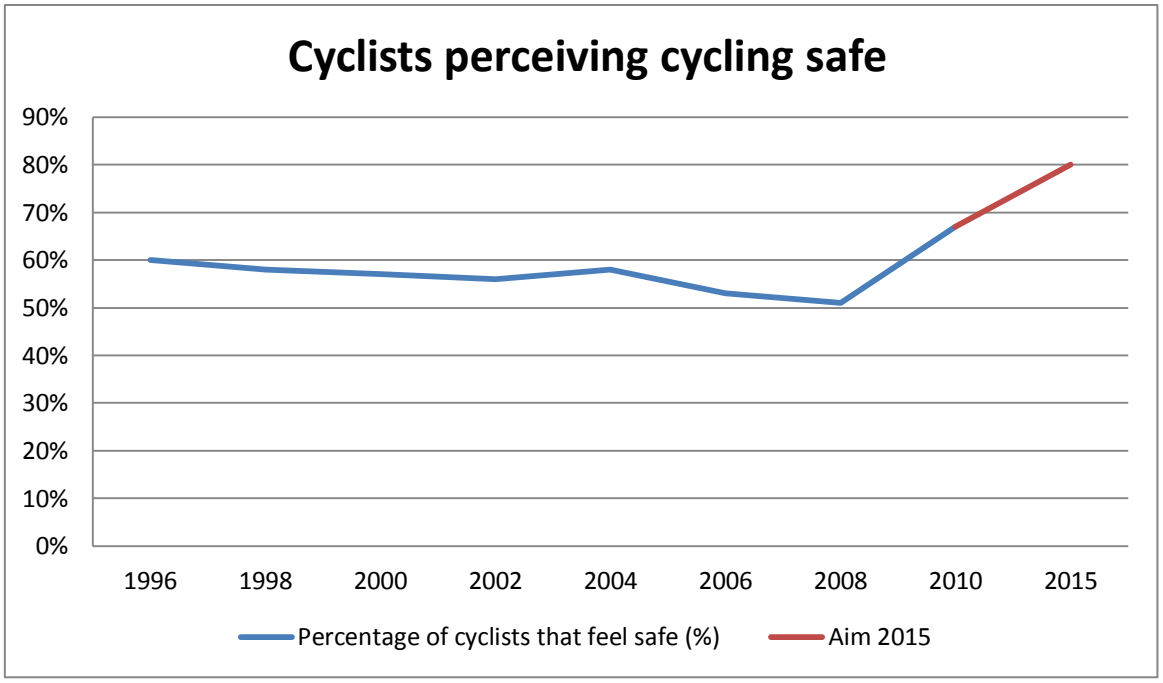
4.7.1 Safety Copenhagen

As already discussed earlier Copenhagen doesn't have many cycle lanes, but focused their road infrastructure on cycling tracks. In 2010 the city had 346 km cycle tracks and only 23 km cycle lanes. Also the raised cycle tracks, as discussed earlier create a rather safe environment for cycling. The safety of cycling can be recognized in the number of injuries: Between 1996 and 2008, the percentage of cycling commuters rose from 30 to 37%, while the number of injuries decreased by 50% (Buehler & Pucher, 2012b). The following graph shows the development of serious injuries since 1996, showing a dropping trend.



Graph 29: Number of serious injuries (City of Copenhagen, 2010; own visualization)

While there has been no big difference since 1996 in the perceived safety of cyclist, moving around 60%, the city of Copenhagen is aiming to reach 80% by 2015, as shown on the graph below.

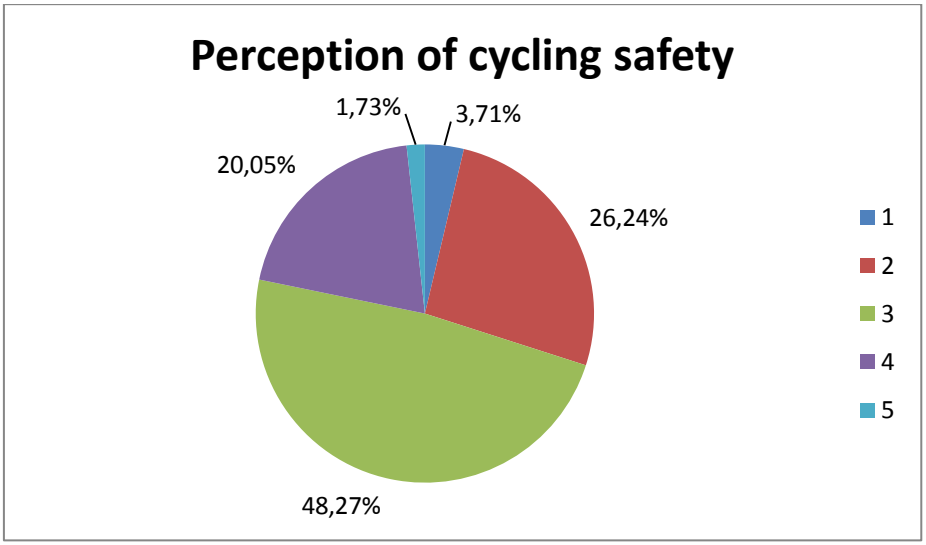


Graph 30: Cyclists perceiving cycling safe (City of Copenhagen, 2010)

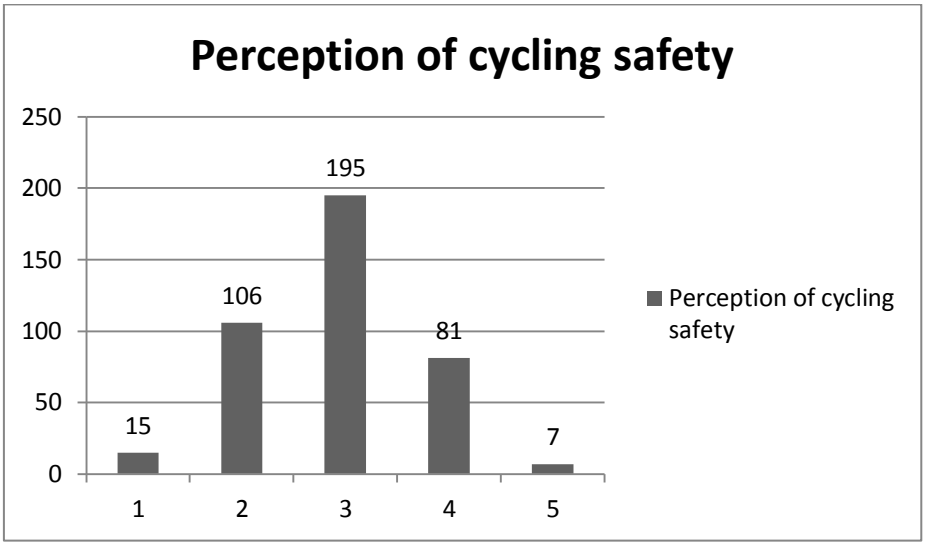
The cyclist fatality rate per 10,000 daily commuter cyclists is 0.3 in Copenhagen (Buehler & Pucher, 2012b).

4.7.2 Safety Berlin

The cyclist fatality rate per 10,000 daily commuter cyclists in Berlin is 0.6, which is double as high as the rate for Copenhagen (Buehler & Pucher, 2012b). According to my survey, the perception of safety was rated 2.9 on a scale of 1 to 5, with 48.27% of the participants choosing rating 3.

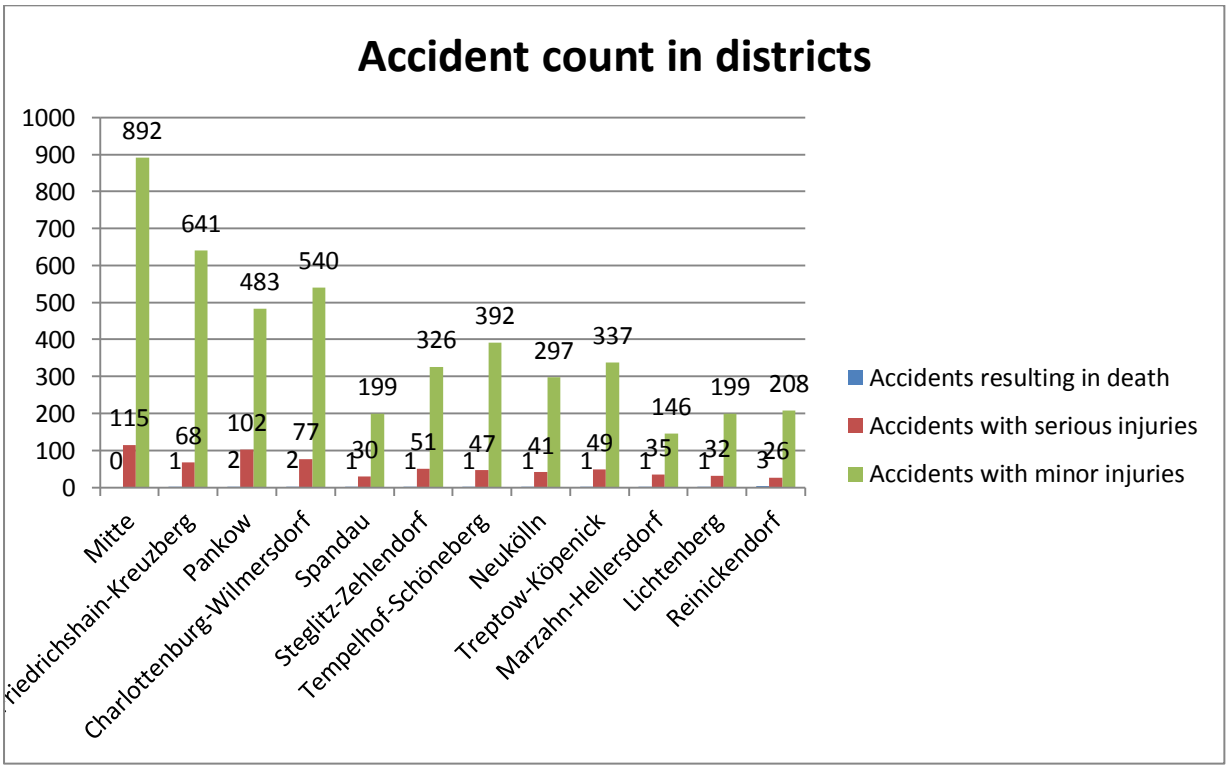


Graph 31: Perception of cycling safety (Own survey)



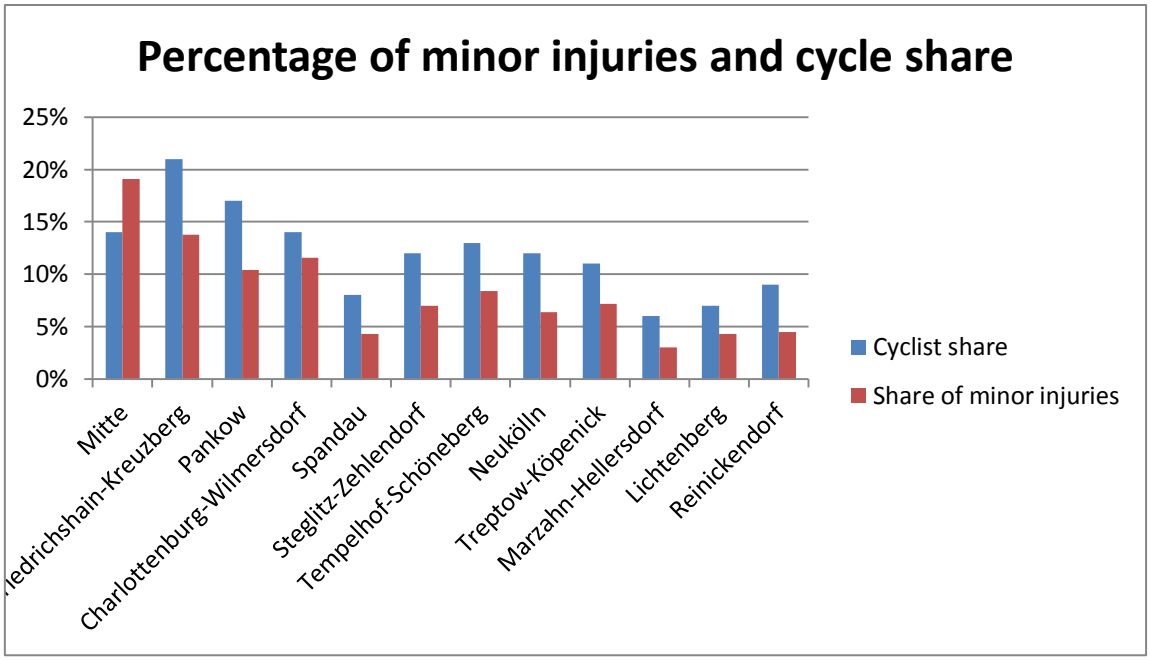
Graph 32: Perception of cycling safety (Own survey)

The following graph shows the distribution of accidents, sorted according to their severity and district.



Graph 33: Accident count in districts (Der Polizeipräsident in Berlin, 2012)

When comparing the percentage of accidents (minor injuries) with the cyclist share of the respective district, there is a degree of correlation.



Graph 34: Comparison of percentage of minor injuries and the cycle share in districts (Der Polizeipräsident in Berlin, 2012)

While in Denmark there is a consensus that cycle tracks are the safest cycling infrastructure and are widely accepted both in society and by planning officials, in Berlin this is not the case. The survey showed that an overwhelming part of the participants would prefer to have on street cycle lanes. When looking into discussion on social media, among groups who are active in the cycling scene, there is a very strong presence of the opinion according to which on street cycling is safer than on cycle tracks.

4.8 Traffic calming

4.8.1 Traffic calming Copenhagen

Traffic calming plays an important role in the safety of cyclists. Collisions of vehicles and cyclists below the speeds of 32km/h are rarely fatal (Jacobsen & Rutter, 2012). Copenhagen has both car-free zones and reduced car parking in the city center, while many residential neighborhoods are traffic calmed with speed limitation at 20 or 30 km/h (Buehler & Pucher, 2012b). It has become common to create an upper limit for car parking in central areas, in order to reduce the number of parking spaces in new projects. Denmark has so called slow speed zones, which limit speeds to 30-40 km/h, traffic calmed streets with limits of 30 km/h and living streets with a speed limitation of 15 km/h. These tools allow speed limitations in large urban areas (Andersen et al., 2012).

4.8.2 Traffic calming Berlin

Berlin has an extensive network of traffic calmed streets. The following map shows in red all the areas of the city, which have a 30 km/h speed limit.

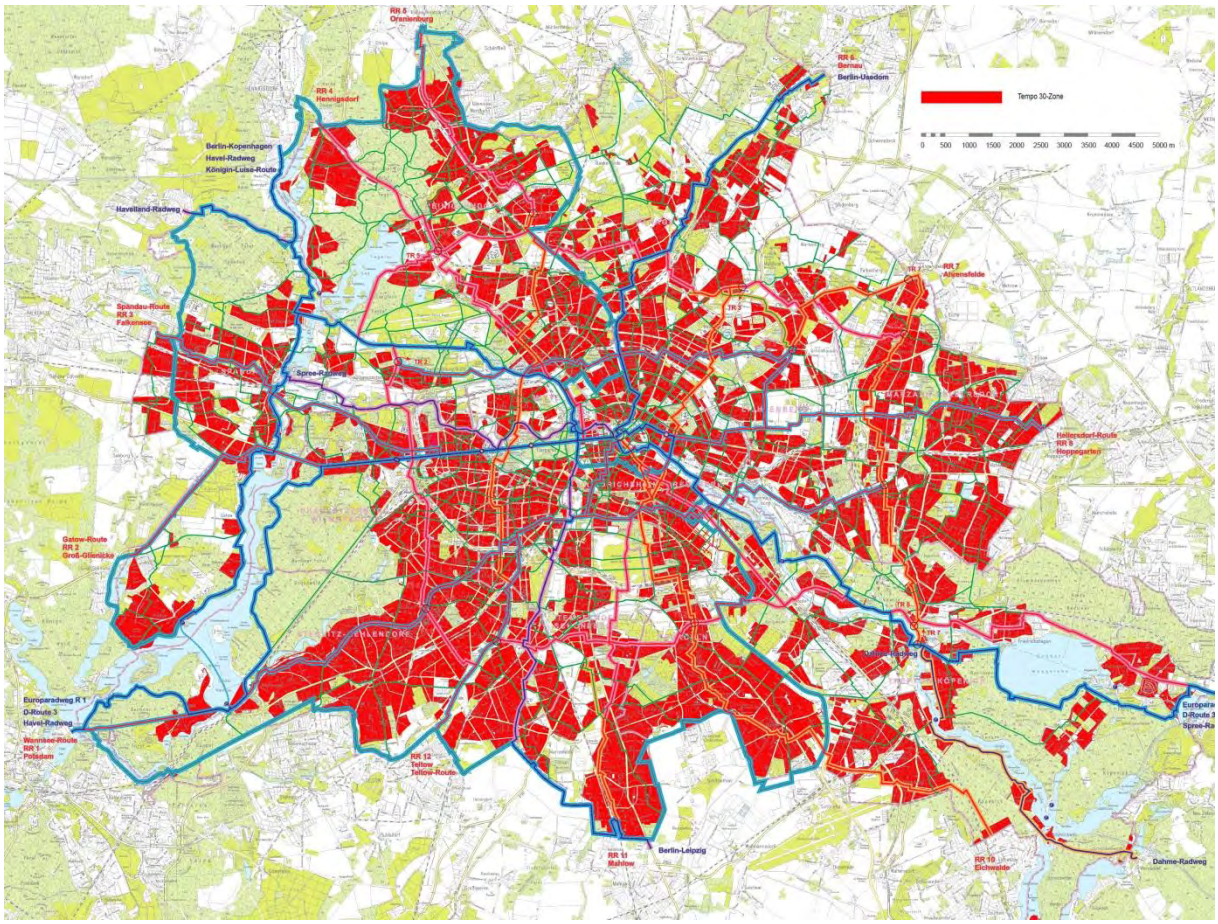


Image 33: 30 km/h areas in Berlin (FIS-Broker, 2013)

As it can be seen on the map, most of this traffic calmed areas are developed at a neighborhood scale, arterial roads are not part of traffic calming. When developing cycling infrastructure, Berlin has a big potential in these traffic calmed areas.

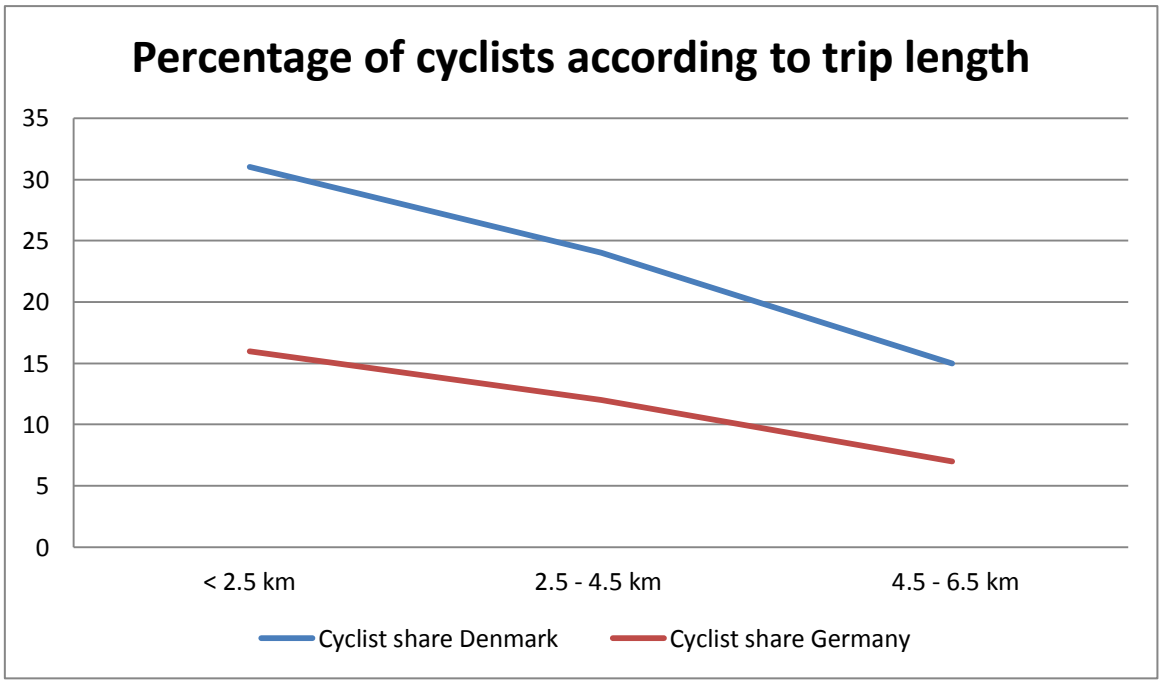
Berlin furthermore introduced a street typology called Cycling Streets (“Fahrradstraße”), in which cyclists are allowed to cycle next to each other, the speed should be controlled by cyclists and cars are limited to 30 km/h (Bezirksamt Charlottenburg-Wilmersdorf, 2013). In my survey this street typology was rated rather well, and there was an interest shown in expanding these streets.

Image 34: Signage for cycle streets (Own image) and an example for a cycle street (Own image)

4.9 Land use planning

The majority of urban trips are over short distances, which makes non-motorized modes of transportation a viable option for urban mobility (Rodrigue, 2013). Higher population density and greater mixes of land use lead to shorter trips, while also making public transportation more viable and decreasing average car speeds. On the other hand density can also lead to higher traffic volumes, potentially discouraging from cycling.

Historically Northern-European countries have a longer tradition of mixed-use zoning and transit oriented developments (Buehler & Pucher, 2012b). In Denmark and Germany 40% of all trips are shorter than 2.5 km. The bike share for trips shorter than 2.5 km is 31% in Denmark and 16% in Germany, between 2.5 and 4.5 km its 24% in Denmark and 12% in Germany and between 4.5 to 6.5 km, 15% in Denmark and 7% in Germany. There is a clear tendency of dropping bicycle share as the travel distance grows (Buehler, et al., 2009).



Graph 35: Percentage of cyclists according to trip length (Buehler, et al., 2009; own visualization)

A general aim should be to shorten transport distances for shopping facilities, which means that newly designated shopping areas should be located in central areas of the city. The redevelopment of abandoned but central areas, for instance port areas can contribute to cycling, if the number of car parking spaces is kept low (Andersen et al., 2012).

4.9.1.1 Public transport

Ideally cycling infrastructure should be planned in coordination with the public transportation network, encouraging both modes of transportation, while allowing for intermodality. The cycling network should integrate nodes of public transport (Pucher & Buehler, 2012b).

4.9.2 Land use planning Copenhagen

In Copenhagen, when answering the biannual survey of the city, cyclists argue that they choose the bicycle because it is the fastest and easiest mode (Dutch Bicycle Council, 2006). In order to have a high cycling share it is important to plan infrastructure in a way, that it guarantees an easy and fast access to destinations. The destinations of cyclists are generally schools, institutions, workplaces, shops, parks, leisure facilities, train stations and bus stops (Andersen et al., 2012).

The denser the urban structure the higher the modal share of cycling. The following graph shows the outcome of a study, which linked the size of Danish cities to the cycle share. The graph shows a tendency, that the smaller the population of a city is the lower the share of cyclists.

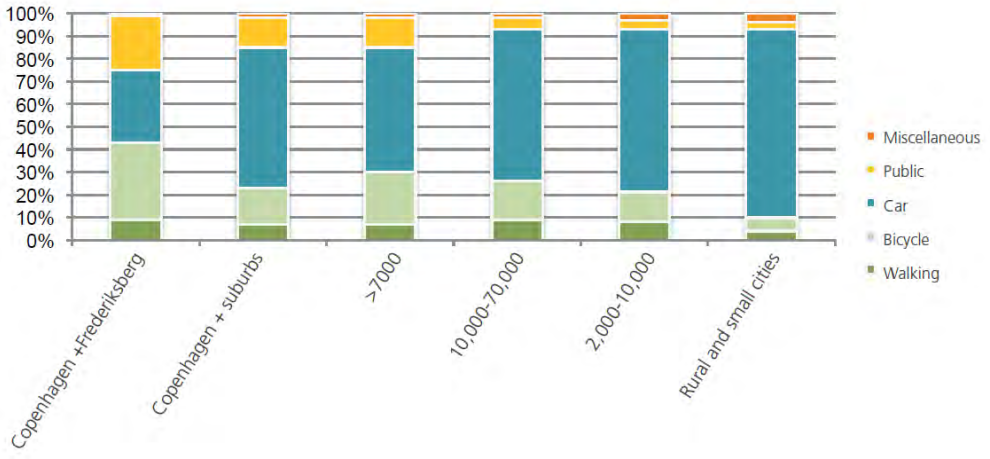


Image 35: Distibution of transport modes in relation to urban structure (Andersen et al., 2012)

In order to limit urban sprawl, Denmark has introduced policies, which regulate that new developments, both residential and commercial, have to be established in areas with an easy access to public transport (Andersen et al., 2012).

The following map was developed to show the distances from a cyclist's perspective from the city center. The distances are rough numbers, since some routes might take less or more time. The calculation was done based on Google Maps calculations for cyclists.

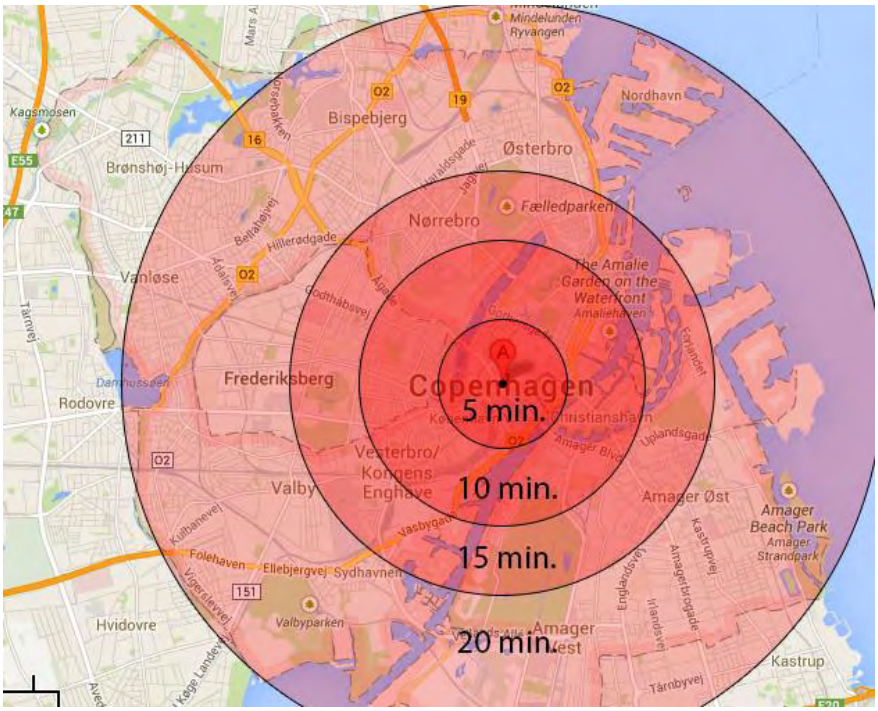


Image 36: Travel times for cyclists (Google Maps, own visualization)

4.9.2.1 Public transport

25% of rail passengers in Denmark use their bikes to reach their station (Pucher & Buehler, 2012b), although with a better integration of public transport and bicycle planning, intermodal trips could be increased (Andersen et al., 2012). In the new urban development of Nordhavnen, in Copenhagen the traffic rules are developed so that the most direct and easiest way of transport is on bicycle or public transport.

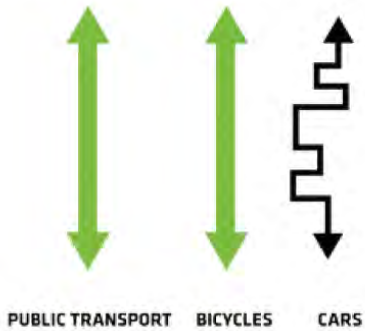


Image 37: Traffic policy for a new development (Andersen, et al., 2012)

4.9.3 Land use planning Berlin

The following map shows travel times by bicycle in Berlin. If comparing the city scale it is clear that the distances in Berlin are much longer.

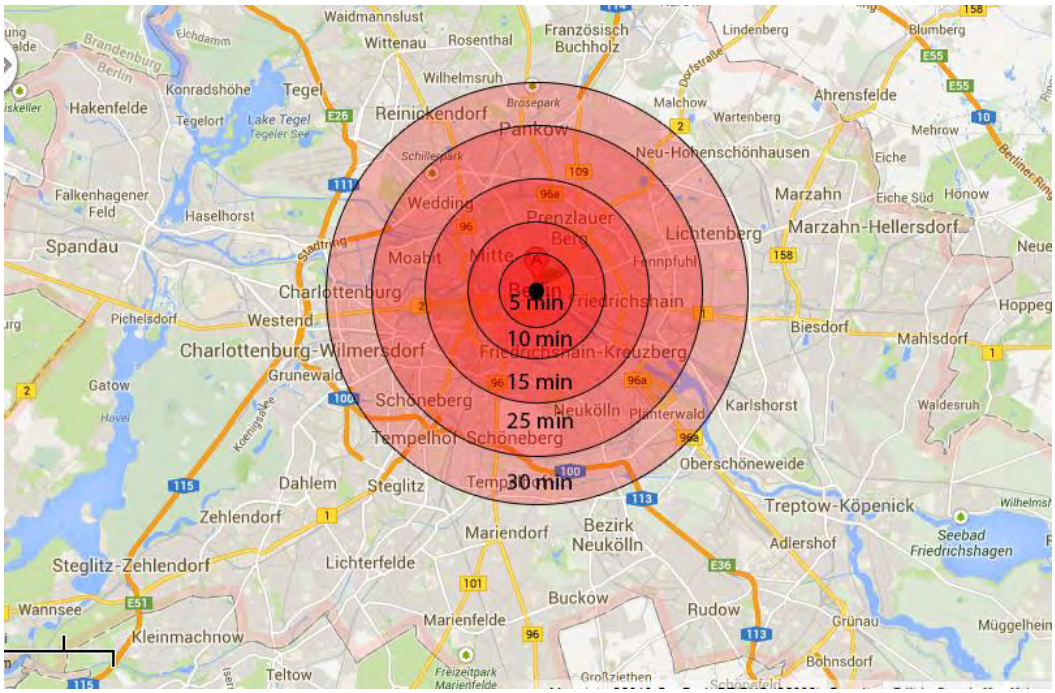


Image 38: Travel times for cyclists (Google Maps, own visualization)

The following map shows the population density in Berlin. This map will be further elaborated in chapter 5.

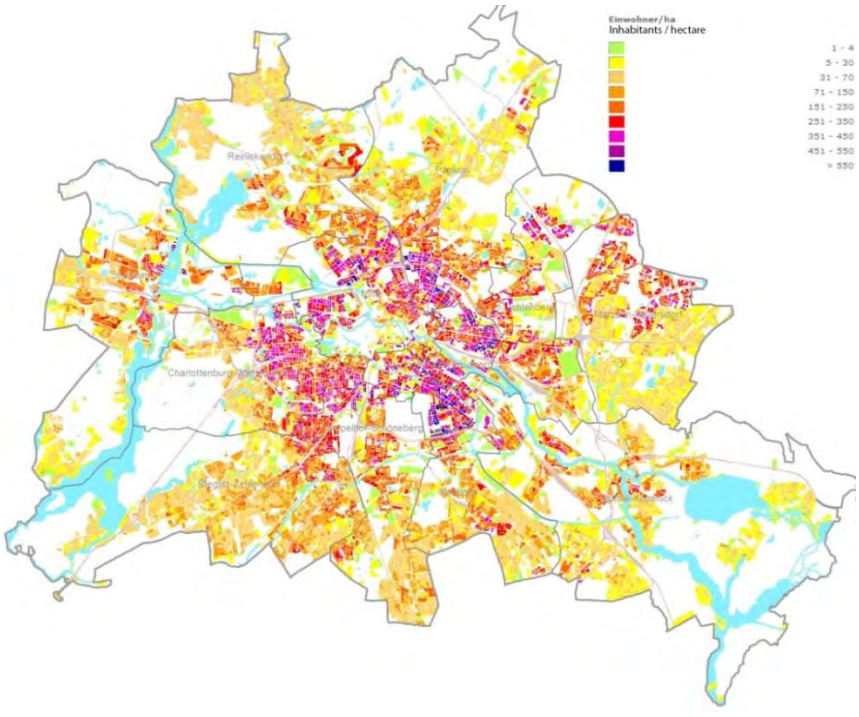


Image 39: Population density in Berlin (FIS-Broker, 2013)

In order to have a better overview of central Berlin, the following map shows the inner city.

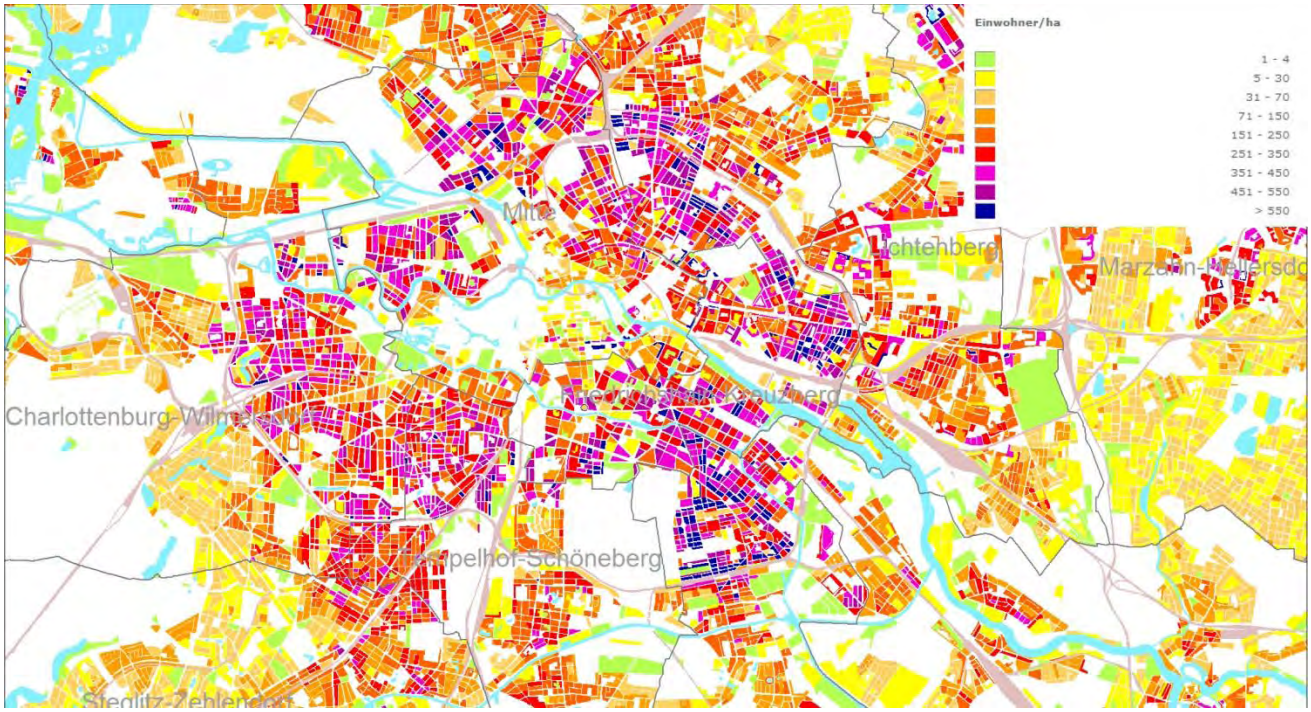


Image 40: Population density in the inner city (FIS-Broker, 2013)

The following map shows the traffic count provided by the city of Berlin, measuring the average daily traffic flow on a workday.

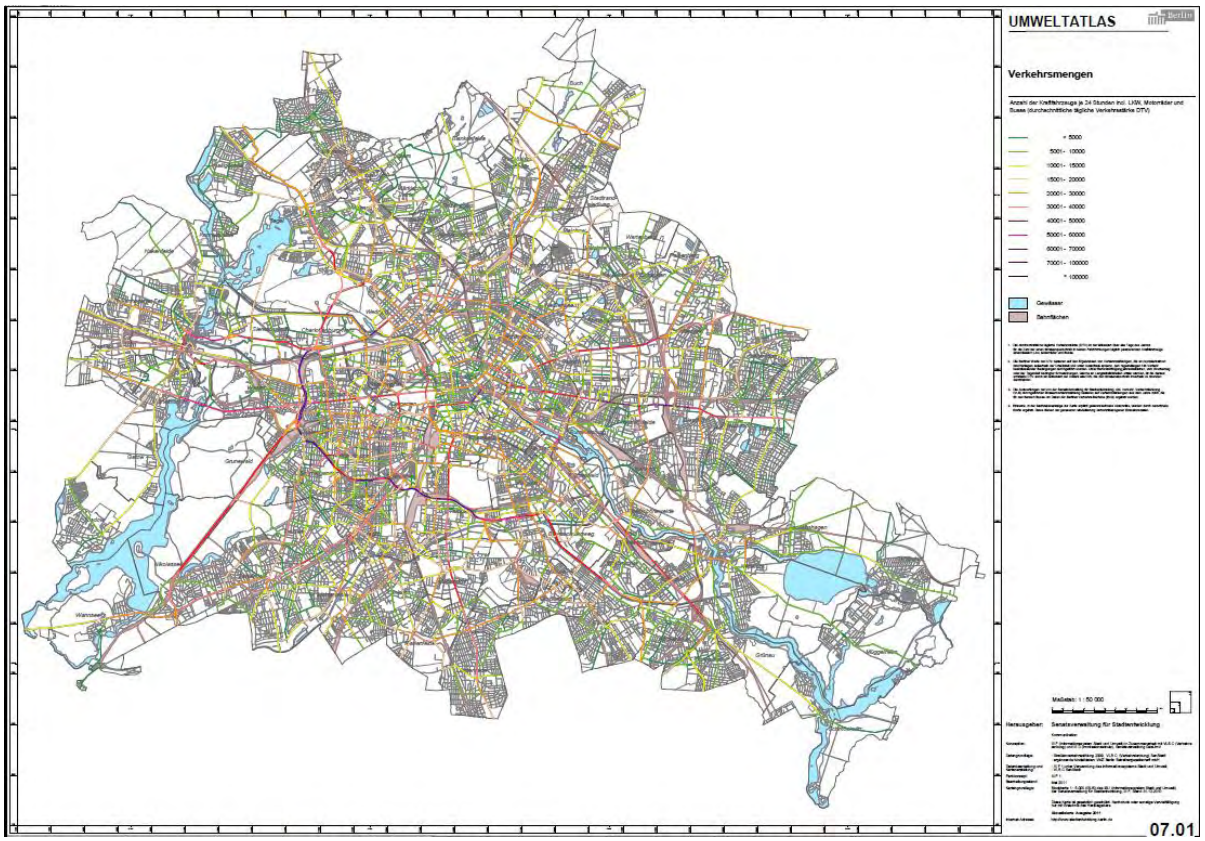


Image 41: Traffic count (Senatsverwaltung für Stadtentwicklung, 2011b)

4.9.3.1 Public transport

For 10 Euros it is possible to take a bicycle on international trains, while for 9 Euros on national trains. There are also regional tickets available for 5 Euros, but the specific pricing varies in the different regions (Bahn.de, 2013). The S-Bahn (S-train) allows bicycles, while on the metro system they are only allowed on specifically marked trains. In busses it is generally not allowed to take a bicycle. The ticket for the bicycle costs between EUR 1.70 and EUR 2.30 depending on the number of travel zones used (Berlin.de, 2011).

Other factors

4.10 Bike sharing

4.10.1 Bike sharing Copenhagen

Copenhagen had the first large scale bike-sharing programme in Europe in 1995 called “Bycyclen”. This was a second generation, or coin-deposit system. A 20 Danish kroner coin was needed to unlock it and towards the end of the scheme there were around 2000 bicycles in 110 locations throughout the city (Shaheen, et al., 2012). The major problem with the system was that due to the deposit system there was a customer anonymity, which didn’t guarantee users taking care of the bikes (Shaheen & Guzman, 2011). As of 2012 Copenhagen does not have a bike sharing system, but a new information technology–based bike sharing scheme is planned to be launched by the end of 2013 (Copenhagen Post, 2013).

4.10.2 Bike sharing Berlin

Berlin has a bike sharing system, named “Call a bike”, which is run by Deutsche Bahn. Its cost 8 Eurocents for a minute of bike rental, but there are yearly subscriptions, which make the first 30 minutes of bike rental free (DB AG, 2010). The following map shows the bicycle stations.

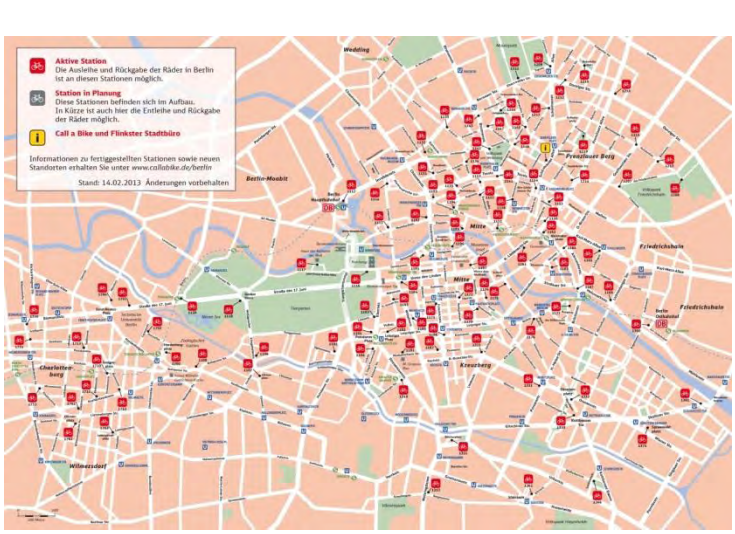


Image 42: “Call a bike” stations (DB AG, 2013) and a “Call a bike” station (own image)

4.11 Bicycle parking and security

4.11.1 Bicycle parking and security Copenhagen

The insufficient bicycle parking facilities is the biggest lack of cycling infrastructure in Copenhagen according to the users, at is shows in the Bicycle account carried out every second year in Copenhagen. There are 6,960 parking spaces per 100,000 inhabitants in Copenhagen. In comparison, there are 30,272 parking spaces per 100,000 inhabitants in the city of Amsterdam, which is also described as insufficient in rush hours (Buehler & Pucher, 2012b).

4.11.2 Bicycle parking and security Berlin

In Berlin there are only 857 bicycle parking spaces, per 100,000 residents, which is only 12% of the parking facilities in Copenhagen (Buehler & Pucher, 2012b). According to the survey I carried out, there is a demand for, especially safe cycle parking in Berlin.

4.12 Health & Social status

4.12.1 Health and social status Copenhagen

While cyclists in Copenhagen say that they choose cycling foremost because it is the fastest and easiest way of transportation, the second most given answer is because it is healthy (Dutch Bicycle Council, 2008). Cycling promotion is an integral part of health policies (Andersen et al., 2012). Cyclists choose their mode of transportation as a conscious and rational decision. Cycling levels are high among all social and age groups, while being evenly distributed over all income categories. This is a difference in comparison to car owners, who usually have a higher income or public transport, which is typical for lower incomes. It is common to see ministers or city executives commuting by bicycle (Dutch Bicycle Council, 2006).

4.12.2 Health and social status Berlin

There is no comparable information available for Berlin as the survey carried out by the city of Copenhagen. My survey however revealed that there is a broad dissatisfaction with both car drivers' behaviour and the actions of the police in regard to cyclists' interests. A common complaint was that cars are often parked on the cycle lanes and tracks, and there is no perceived effort by the officials to prevent this. This can potentially be in connection to the low social and political acceptance of cyclists. The opinion of cyclists in regard to both car drivers and insufficient control of cycle lanes were confirmed by Martin Schlegel. He pointed out that in a survey carried out by ADFC found these two complaints as well.

4.13 Government and Policies

Policies, which are not directly related to the built infrastructure, play an important role in the development of cycling in cities. In Denmark it has played an important role in developing cycling that there is a strong and long-term support from the government (ECMT, 2004). Not only the governments, but also the public support can help projects become successful (Andersen et al., 2012).

The best way to achieve an increase in cycling is to create better cycling conditions, but at the same time making the conditions of car ownership more difficult (Andersen et al., 2012).

Communities in Denmark have the possibility to give bicycle parking norms for new projects, ensuring bicycle parking facilities (Andersen et al., 2012).

4.13.1 Government and Policies Copenhagen

The policy approach of Copenhagen is based on offering cyclists a better offer through good infrastructure and promoting cycling, while there are general restrictions on motor traffic in the form of parking restrictions and fees (Andersen et al., 2012).

4.13.1.1 Monitoring Copenhagen

The city of Copenhagen has introduced a tool in order to monitor cyclists need on a regular basis. The Bicycle Account is a biannual survey of cyclists, in which cyclists evaluate the performance of the cycling system, while they can suggest improvements. The survey has been assessed since 1995 and offers a continuous documentation of cyclists needs (Buehler & Pucher, 2012b). For instance this survey has shown that users rate the lack of good parking facilities as the worst aspect of cycling in Copenhagen (Buehler & Pucher, 2012b). The overall ratings however are high (Dutch Bicycle Council, 2006). If the outcome of the Bicycle Account play an active role in the planning, it can be seen as a tool to democratize planning to a certain extent. The following map shows the locations where there are counting devices located, in order to monitor the number of cyclists. This assessment form is efficient if they are actively used to prioritize tools for making decisions (Andersen et al., 2012).

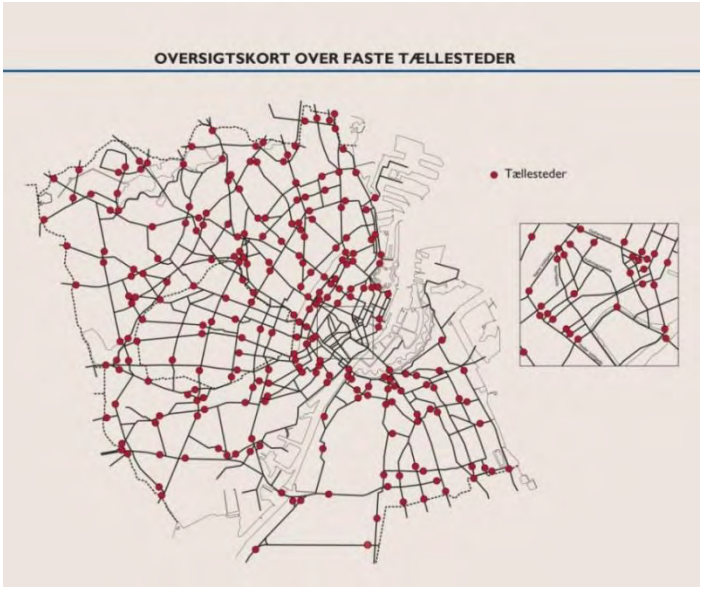


Image 43: Locations of cyclist counting points (Københavns Kommune, 2006)

4.13.1.2 Information and Networking in Copenhagen

There are multiple organizations in Denmark, which promote an information exchange about cycling. The municipal cycle network serves municipal practitioners, who are working with cycling and promotion. Two annual meetings are aimed at the exchange of ideas, experiences and knowledge (Andersen et al., 2012).

The Danish Cyclists Federation was founded back in 1905, in order to represent the interests of cyclist. It is a membership based organization, with 18,000 members in Denmark. They work mainly in the fields of local traffic policies, promotion and cycling tours (Cyklistforbundet, 2013). The aim is to create a cooperation and exchange between the volunteer members of the organization and local authorities in order to create optimal policies and decision (Andersen et al., 2012).

The Cycling Embassy of Denmark is aimed at the cooperation of private companies, local authorities and other organizations. The organization was founded in 2009 and is financed by public funds. Among their tasks are the promotion of Denmark as a cycling country, making knowledge available for non-Danes, supporting evens and arranging classes (Andersen et al., 2012).

4.13.1.3 Finances in Copenhagen

Considering the cost of cycling tracks, in Denmark 1 km of cycling track is estimated at DKK 8 million. The cost of cycling tracks varies between countries while also depend on the exact concrete structure (Andersen et al., 2012). Danish cities spend $11 to $27 per capita on cycling infrastructure (Furth, 2012).

4.13.1.4 Aims and future in Copenhagen

The Bicycle Strategy 2011-2025 puts down the aims for future developments in regard to cycling. Generally the keywords for development are safe, quick and comfortable. By 2015, 50% of commuters should choose cycling. According to Niels Jensen, if the 50% cyclist share should be reached, a combination of some kind of road pricing and better cycling infrastructure is needed. There is also a “PLUSnet” plan, which by 2025 will offer, through green routes, bicycle superhighways and normal routes, a high level of cycling infrastructure with 3 lanes in each direction on 80% of the network. Bicycle and Cargo-bike parking should be developed, missing links in the infrastructure network should be added, contraflow cycling should be allowed, and there should be a general expansion of cycling tracks and lanes by 2015 (City of Copenhagen, 2013d).

In summary following goals are laid down:

Modal split for bicycles	2015	2020	2025
Share of all trips by bicycle to work and school in Copenhagen	50%	50%	50%
Aims of various qualities in regard to cycling			
Share of the network that has three lanes (2010: 25%)	40%	60%	80%
Relative to 2010, cyclists travel time is reduced by	5%	10%	15%
Percentage of Copenhageners that feel safe cycling in traffic (2010: 67%)	80%	85%	90%
Relative to 2005, the number of seriously injured cyclists will fall by	50%	60%	70%
Percentage of Copenhagen cyclists who find the cycle tracks well maintained (2010: 50%)	70%	75%	80%
Share of Copenhageners who think that bicycle culture positively affects the city's atmosphere (2010: 67%)	70%	75%	80%
Source: City of Copenhagen, 2010			

4.13.2 Government and Policies in Berlin

4.13.2.1 Information and networking in Berlin

ADFC (Allgemeiner Deutscher Fahrrad-Club) was founded in 1979 and now serves as an organization lobbying for cycling and actively participating in politics, in relation to cycling. They have representations in over 450 cities in Germany, as in Berlin and 130,000 members. Their main field of work is involved around traffic planning, policies and tourism (ADFC, 2007).

BUND (Bund für Umwelt und Naturschutz Deutschland) is an environmental protection agency, which is involved in the planning of cycling infrastructure. Both organizations have played an active role in developing the cycling strategy for Berlin, which will be discussed later.

Further, in 2003 a Berlin Bicycle Council ("FahrRat") was founded, involving many relevant actors in cycling, such as districts, police, cyclists advocates, experts, public transportation representatives, etc. The aim of the group is to create policy recommendations, which integrate the interests of all actors. They played a big role in developing the cycling strategy of Berlin (Buehler & Pucher, 2012b). According to Martin Schlegel, as an instrument of involving associations, the "FarhRat" works well, although on the frontier of citizen participation there is a need for improvements.

4.13.2.2 Finances in Berlin

Berlin spends EUR 1.50 per inhabitant on cycling infrastructure. According to the national cycling plan 2020, this amount will have to be raised to EUR 8-12 per inhabitant (Starke & Lippert, 2013).

4.13.2.3 Future in Berlin

The city of Berlin has developed a cycle strategy, in which they define future goals. These goals are: Raising the number of trips by bike (from 1.5 million) by 0.6-0.9 million by 2025, raising the average distance cycled by 25%, from 3.7 km to 4.6 km, intermodal trips should be raised from 3% to 5%, fatal accidents should drop by 40%, while other accidents by 30% by 2025, and by 2017, five Euros per inhabitant should be spent on cycling infrastructure. The paper includes many recommendations, which are not quantified, for instance the guideline according to which all intersection will receive special attention for design details. According to this report many older cycling tracks do not live up to contemporary standards, while often being blocked by cars, snow, etc., which will be tackled through renovation and paying more attention to the upkeep (Senatsverwaltung für Stadtentwicklung und Umwelt, 2013a).

The following map visualizes the aim of cycling network, which the city would like to reach. There are three levels of cycling infrastructure: The red lines mark the main network of cycle routes, the blue stands for long distance cycle routes and the green lines mark the supplementary cycle routes. From the historic center of Berlin there are 12 routes leading to the outskirts of the city, which are further connected by a radial cycle route (Senatsverwaltung für Stadtentwicklung und Umwelt, 2013c).

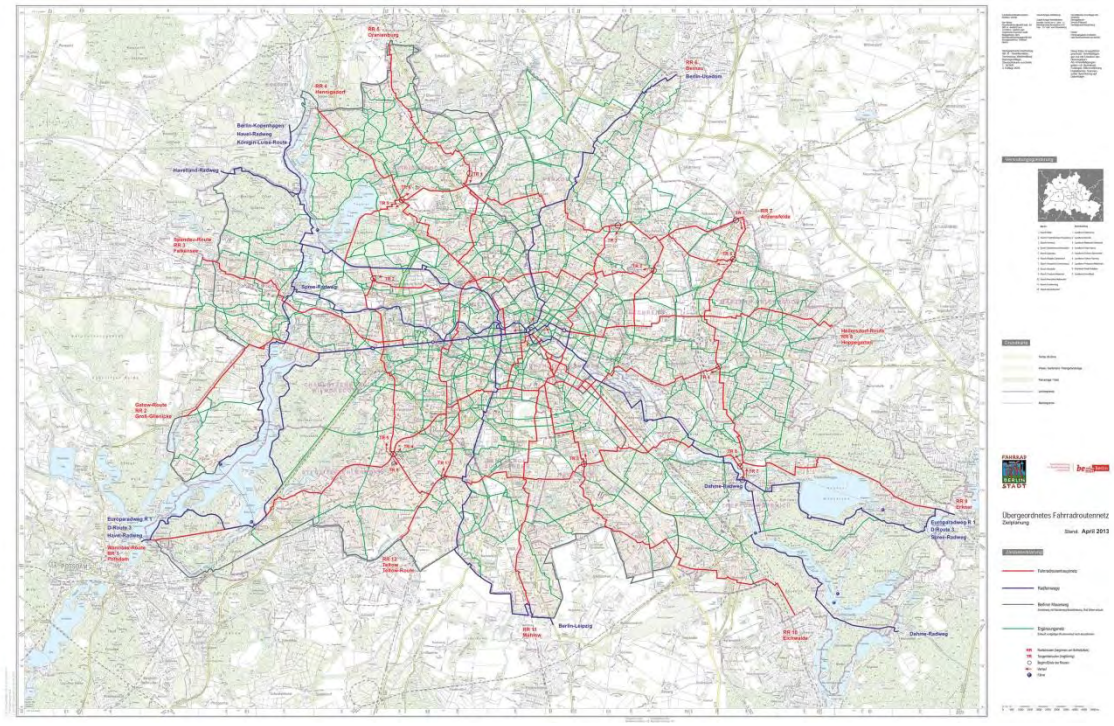


Image 44: The aim cycling network of Berlin (Senatsverwaltung für Stadtentwicklung und Umwelt, 2013b)

5 Planning cycling for Berlin

Based on the analysis, the main issues with the cycling infrastructure in Berlin are the maintenance and design. While the numbers suggest that Berlin has an extensive cycling infrastructure, both the users and officials agree that the infrastructure does not live up to necessary standards. In a publication it is pointed out that disapproval of users towards cycling tracks is often connected to bad experience (Andersen et al., 2012). This could be the case for Berlin, since while the survey of this research showed that there is a broad preference for on road cycling facilities, opposed to tracks, however, Danish literature has a widespread agreement that cycling tracks are the safest infrastructure typology for cyclists.

A plan for cycling infrastructure should be developed based on many factors: the issues and ideas of users, existing cycling patterns, defining primary corridors and user destinations, such as workplaces, retail, public transport, etc. (Andersen et al., 2012).

In the following a spatial analysis identifies a recommended network for Berlin. The network development is focused partially on a city scale but the inner city will be dealt with in more detail. The aspects, which were integrated in the network development, are population density, urban structures and centres, accidents, public transport and traffic flow. Each of these topics are dealt with separately and then integrated into one map, which is the final network recommendation. Since commuting is the main focus of this work, recreational cycling (connecting sites of recreation) will not be discussed.

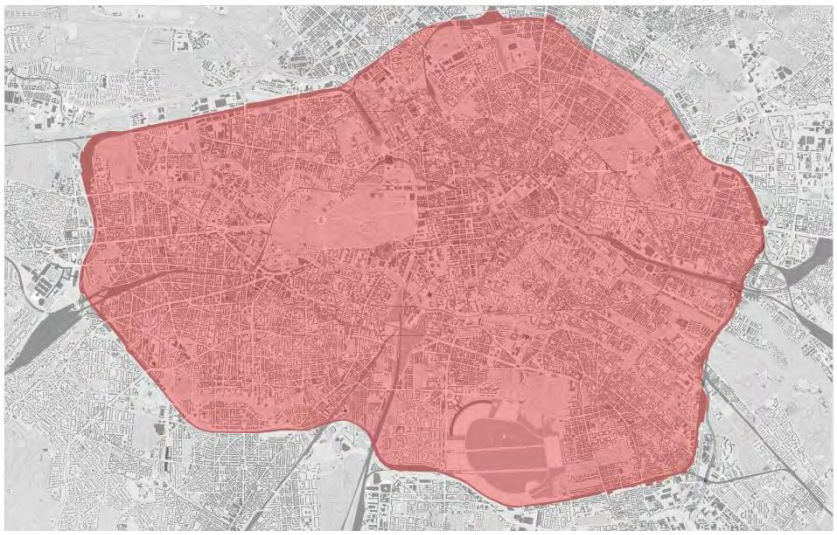


Image 45: Definition of the inner city of Berlin (Senatsverwaltung für Stadtentwicklung, 2010; own visualization)

5.1 Density

The following map has already been used before. The aim is to see how the population density is structured in Berlin, which defines where cycling infrastructure is needed. As it can be seen below, the city has a central area, which has a low population density, surrounded by areas with very high density, which become less dense closer to the outskirts. There are some nodes, which are exceptions, but in general this tendency describes the population density structure.

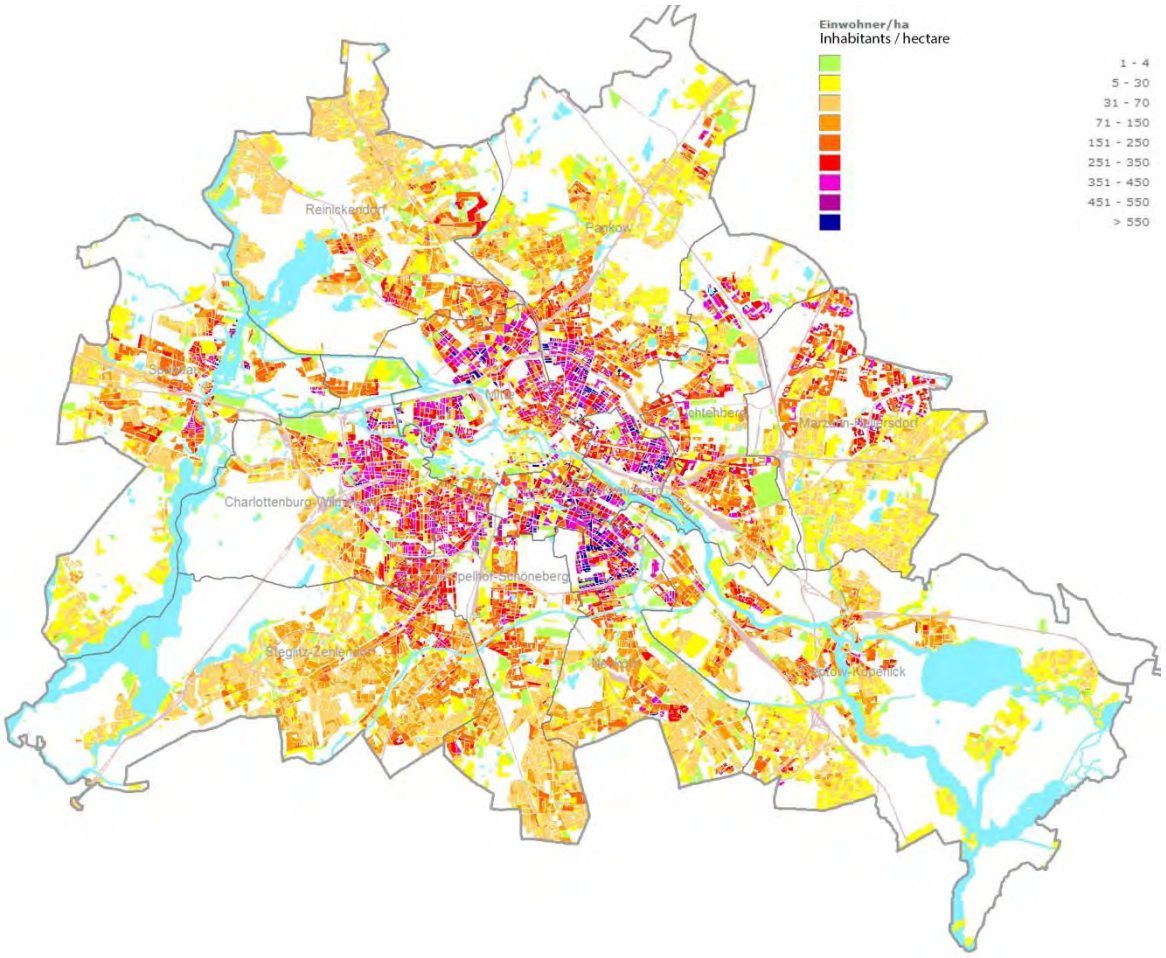


Image 46: Population density in Berlin (FIS-Broker, 2013)

The following map shows the circular density structure of the inner city.

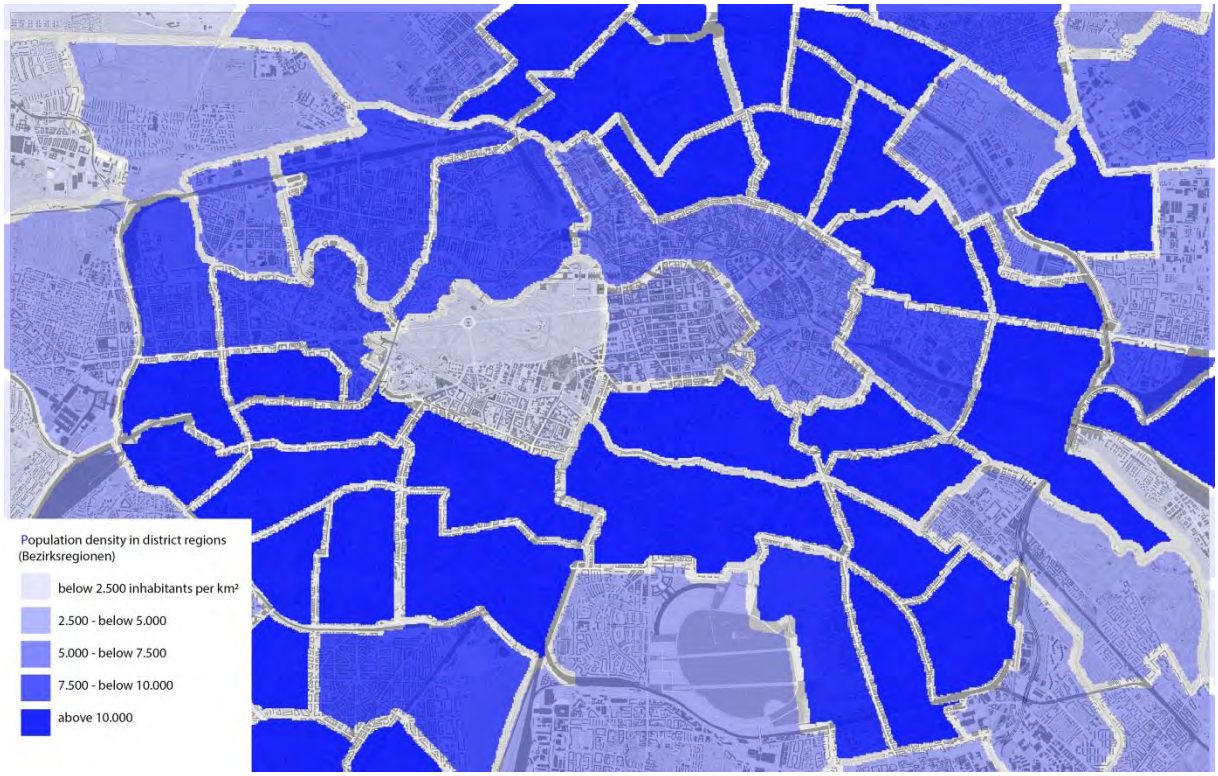


Image 47: Structure of population density (Senatsverwaltung für Stadtentwicklung, 2010; FIS-Broker, 2013)

The map above was turned into the following visualization, to schematize the population density.

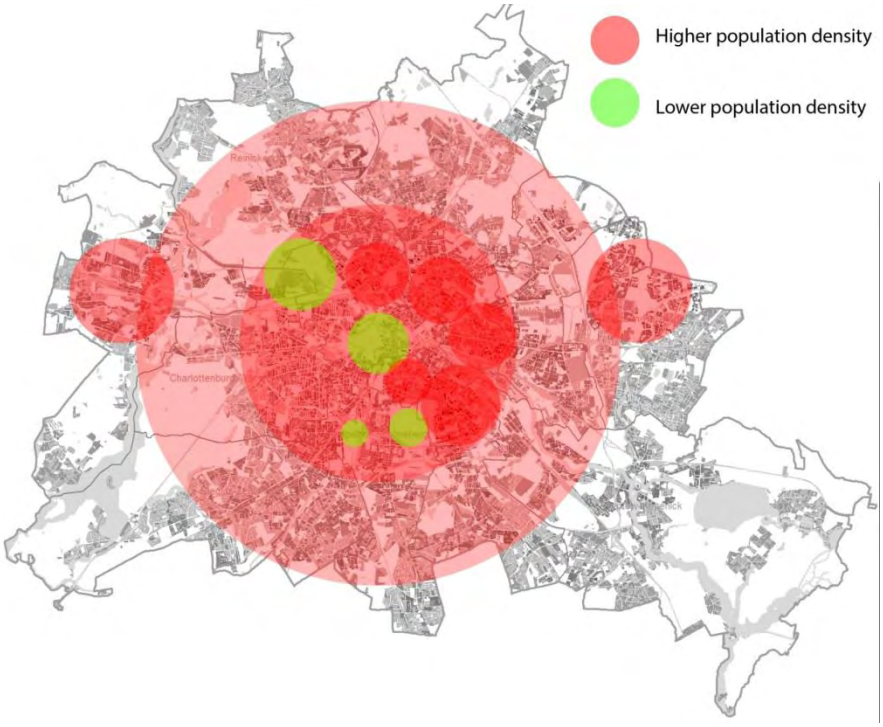


Image 48: Structure of population density (FIS-Broker, 2013; own visualization)

5.2 Urban structure

The low population density in the centre can be partially explained by the typology of the urban structure in it. The following map shows the typology of the urban fabric, the dark brown colour representing core areas of “commerce, services, trade and industry”.

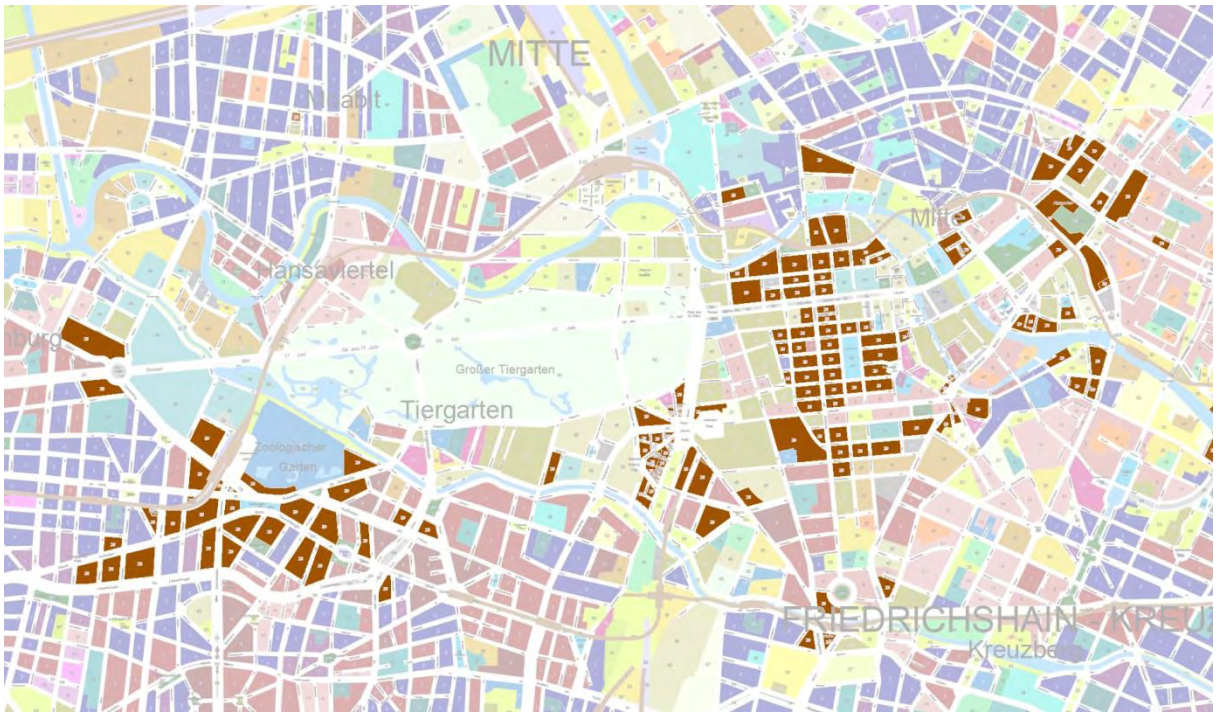


Image 49: Highlighting core areas of commerce, services, trade and industry (FIS-Broker, 2013; own visualization)

5.3 Urban centres

According to the urban development plan focused on commercial centres, it is an important to sustainably integrate large scale retail in the urban fabric. One of the aims of the plan is to assure and develop sub-centres (“Polyzentren”). These centres are important for mobility patterns and play a big role in defining mobility infrastructure needs (Senatsverwaltung für Stadtentwicklung, 2011a). The following map shows the hierarchy of the centres as defined by the development plan. The hierarchy of centres is defined by the size of the symbols.

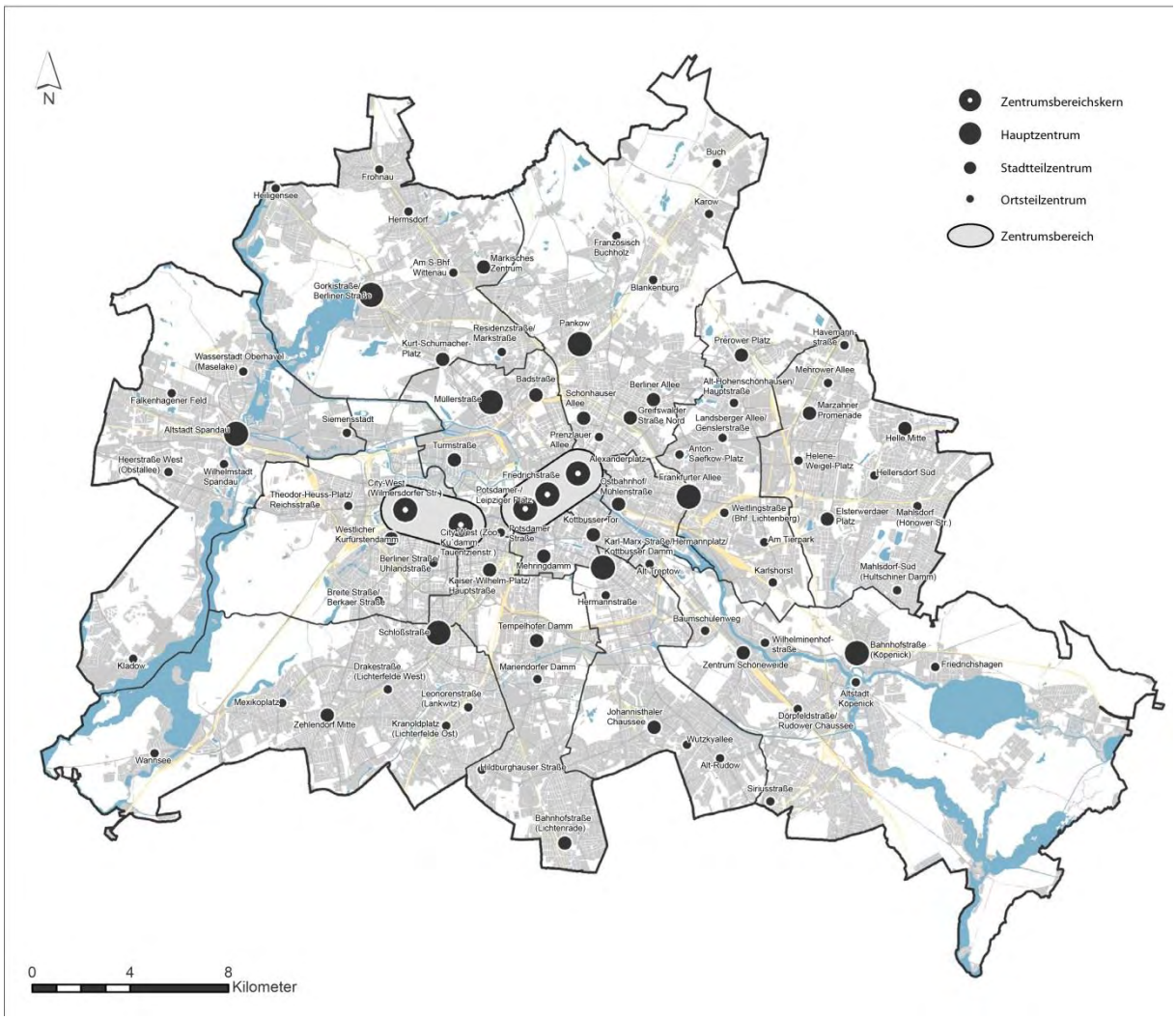


Image 50: Urban centres in Berlin (Senatsverwaltung für Stadtentwicklung, 2011a)

The following map layers the map of the central city and the urban centers described above.

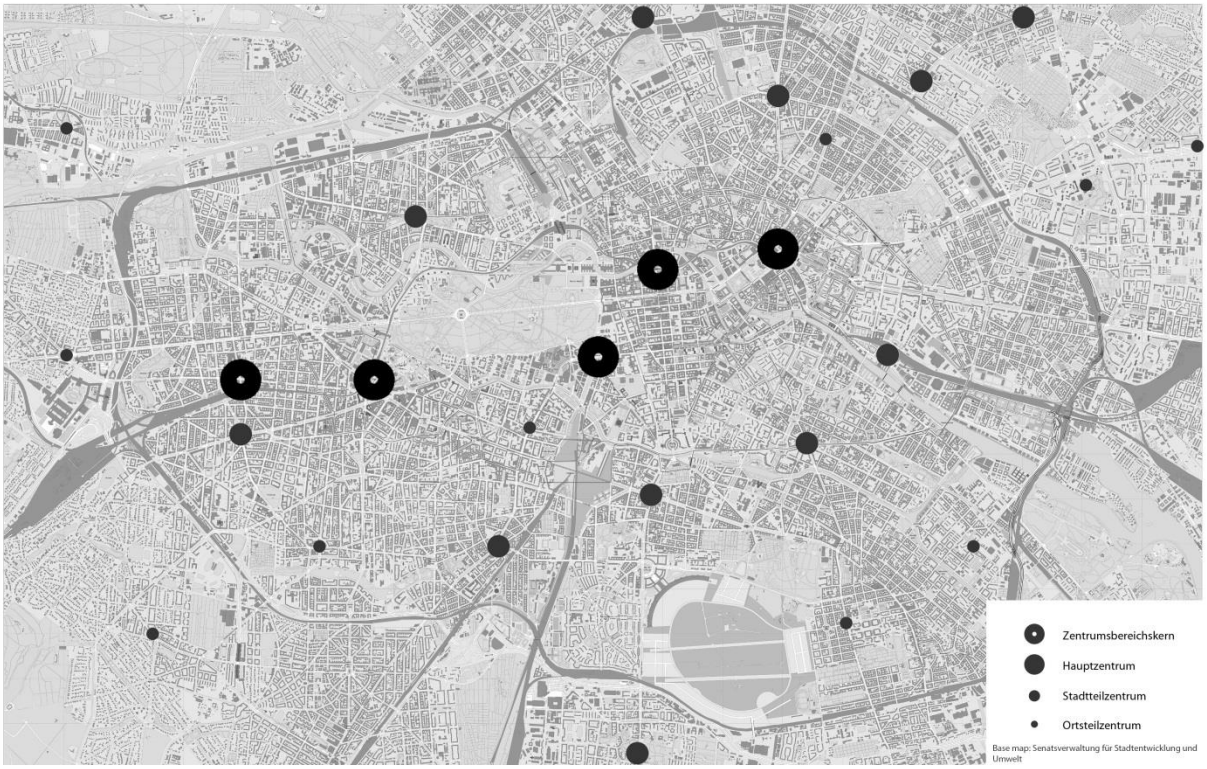


Image 51: Urban centres in the inner city (Senatsverwaltung für Stadtentwicklung, 2010; Senatsverwaltung für Stadtentwicklung, 2011a)

5.4 Street network

The following map shows the street network of Berlin, defined in three main levels. The blue colour stands for roads connecting regional centres with metropolitan areas. The red stands for roads connecting regional centres and local centres. Finally, green stands for roads connecting neighbourhood centres and local centres.

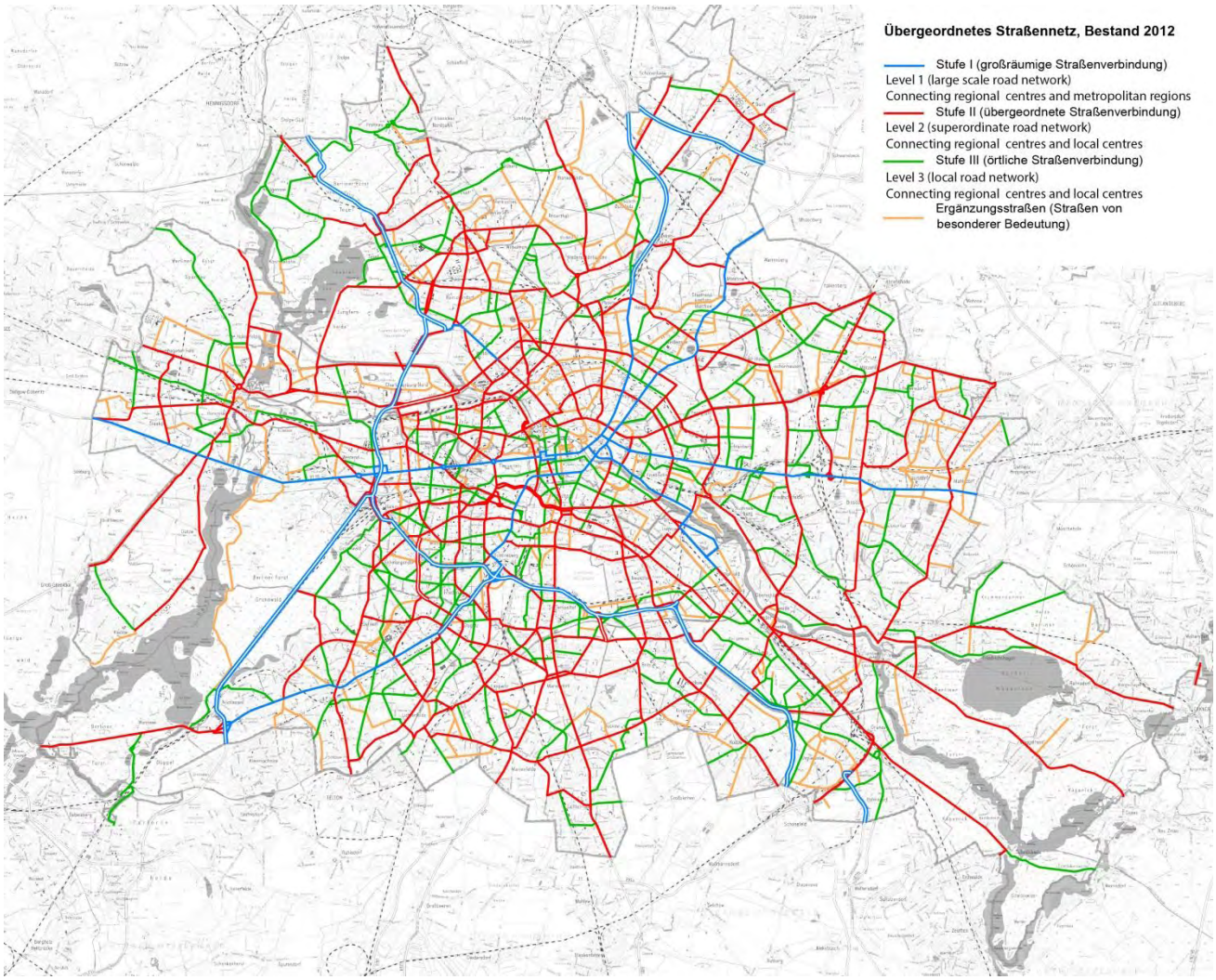


Image 52: Street network of Berlin (FIS-Broker, 2013)

5.4.1 Street network and urban centres

The following map shows that when placing the map of the urban centres on the map of the street network, the urban centres are covered rather well through the street network.

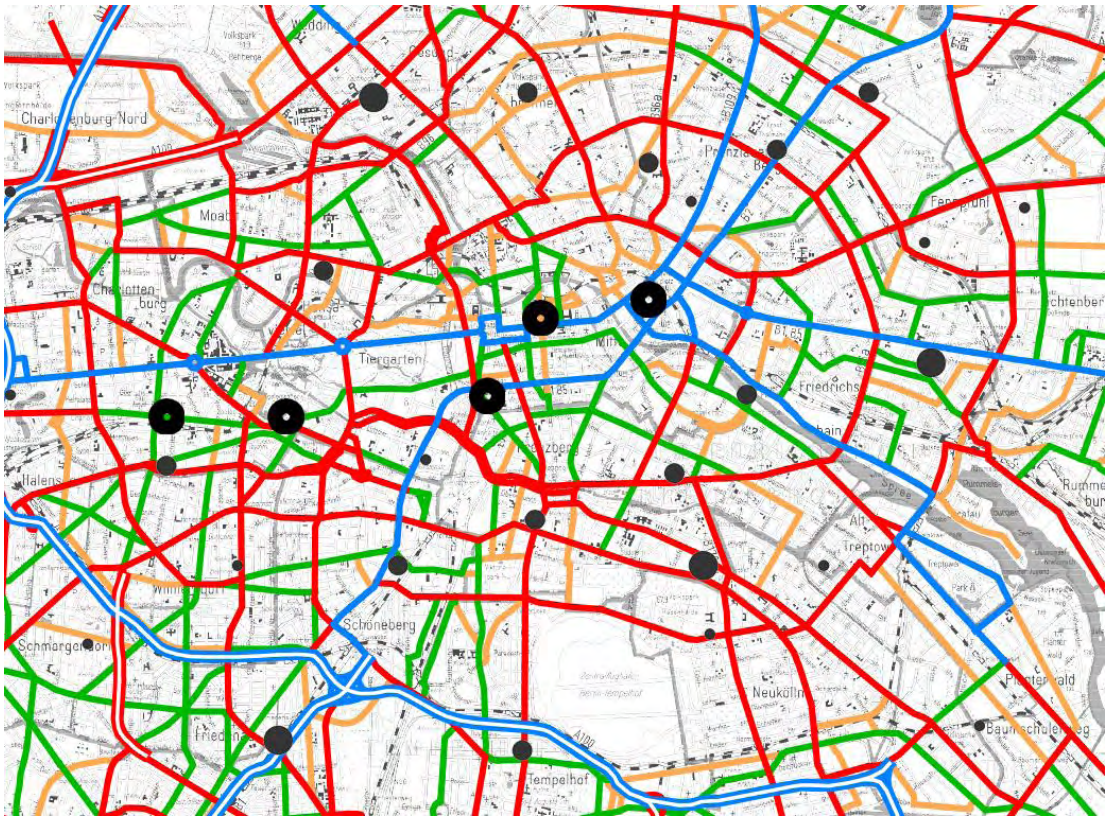


Image 53: Urban centres in the city centre in relation to the road network (FIS-Broker, 2013; Senatsverwaltung für Stadtentwicklung, 2011a)

5.5 Existing cycling infrastructure

The following map shows the existing cycling infrastructure. The four main categories marked on the map are cycling tracks, cycling lanes, advisory lanes and shared bus lanes.

Image 54: Existing cycling infrastructure (FIS-Broker, 2013)

Again the map of cycling infrastructure was layered over the map of the inner city.

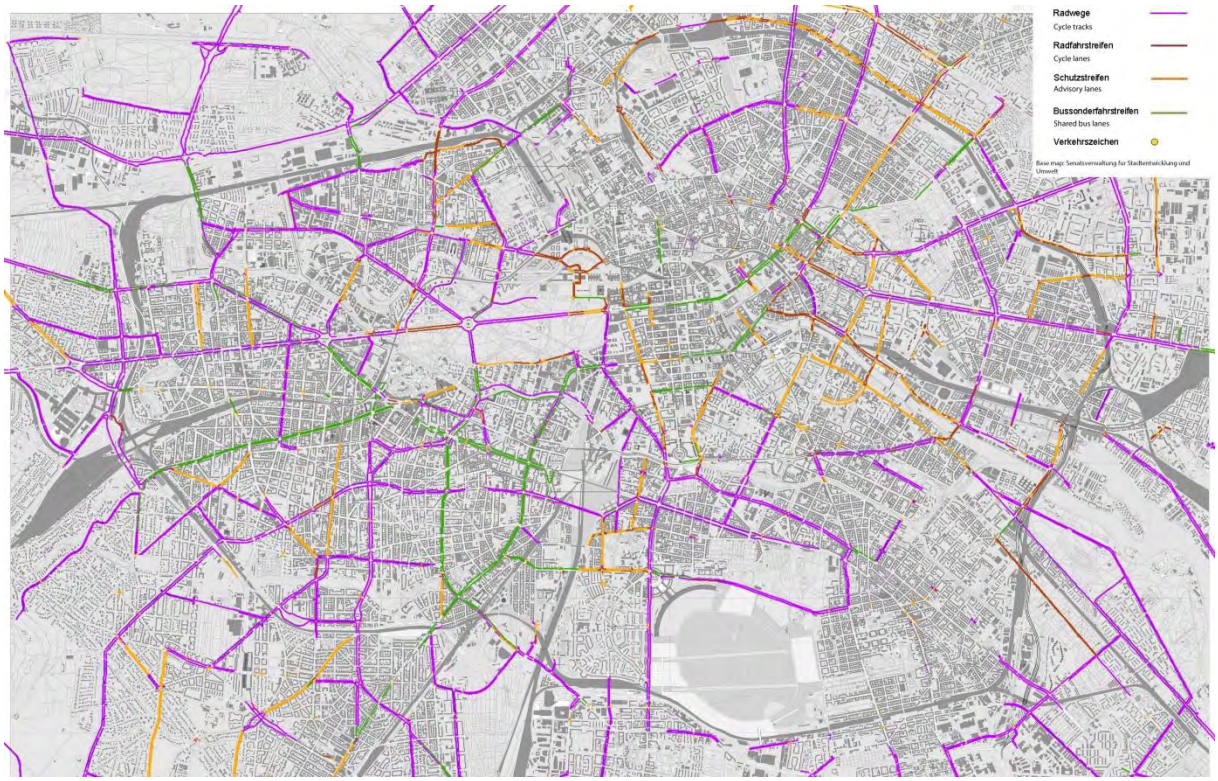


Image 55: Cycling infrastructure in the inner city (Senatsverwaltung für Stadtentwicklung, 2010; FIS-Broker, 2013)

5.1 Accidents

Based on the information provided by the police, I identified the locations where most accidents happened. The registration of an accident happens either according to which street the accident happened on or if it happened at a corner or intersection then all street names are noted. All locations, which had 10 or more accidents, were included in the map, additionally all other accidents were included, which happened on the same street on other corners. The exact list is included in the Annex (8.3.). The focus was set on the city within the circular S-train ("Ringbahn"), so some locations were not noted on the map. Two close-ups are also included, to allow a more detailed view of the map.

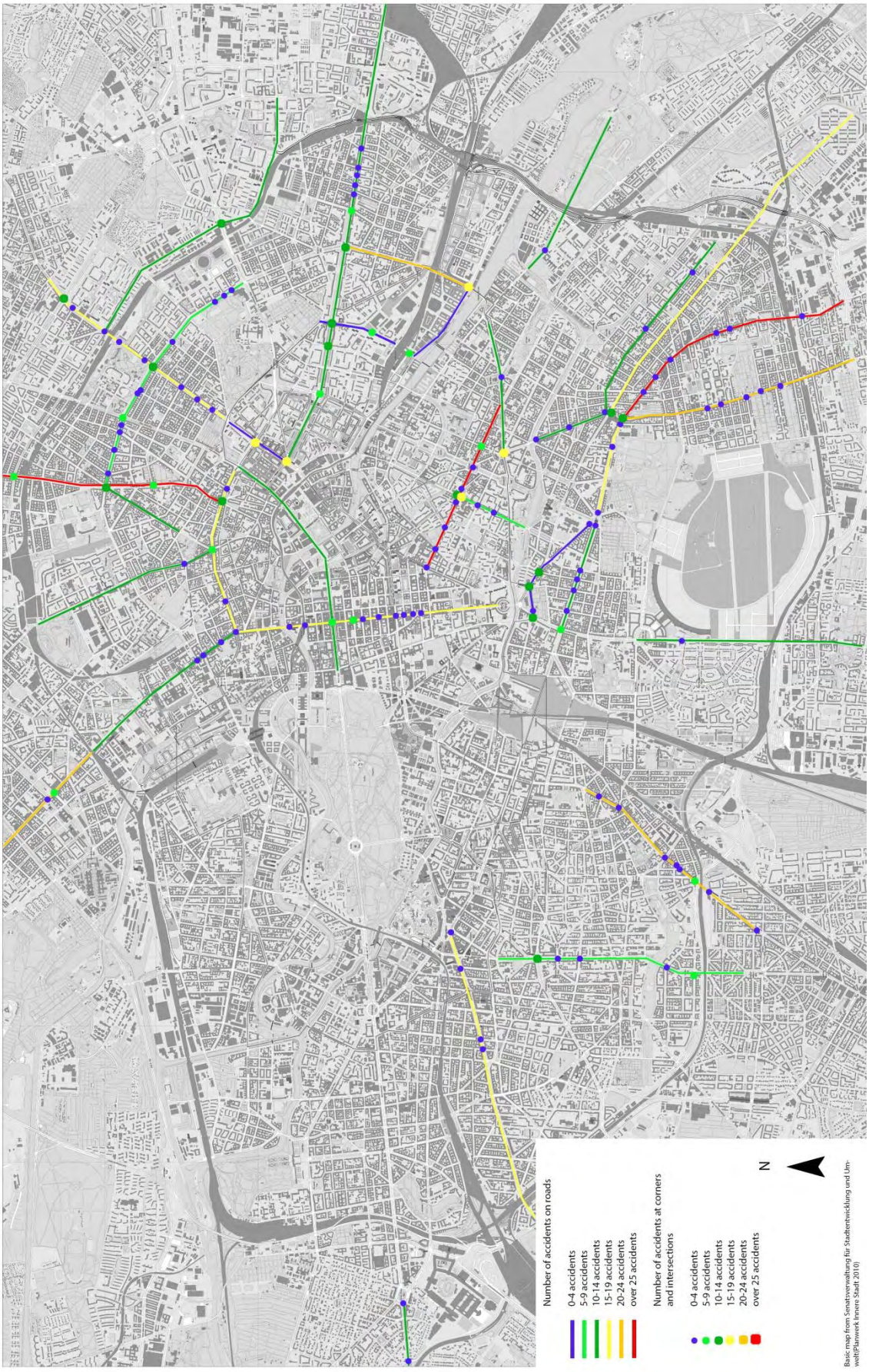


Image 56: Locations with over 10 accidents in the inner city (Own visualization, Base map: Senatsverwaltung für Stadtentwicklung, 2010; Information: Der Polizeipräsident in Berlin, 2012)

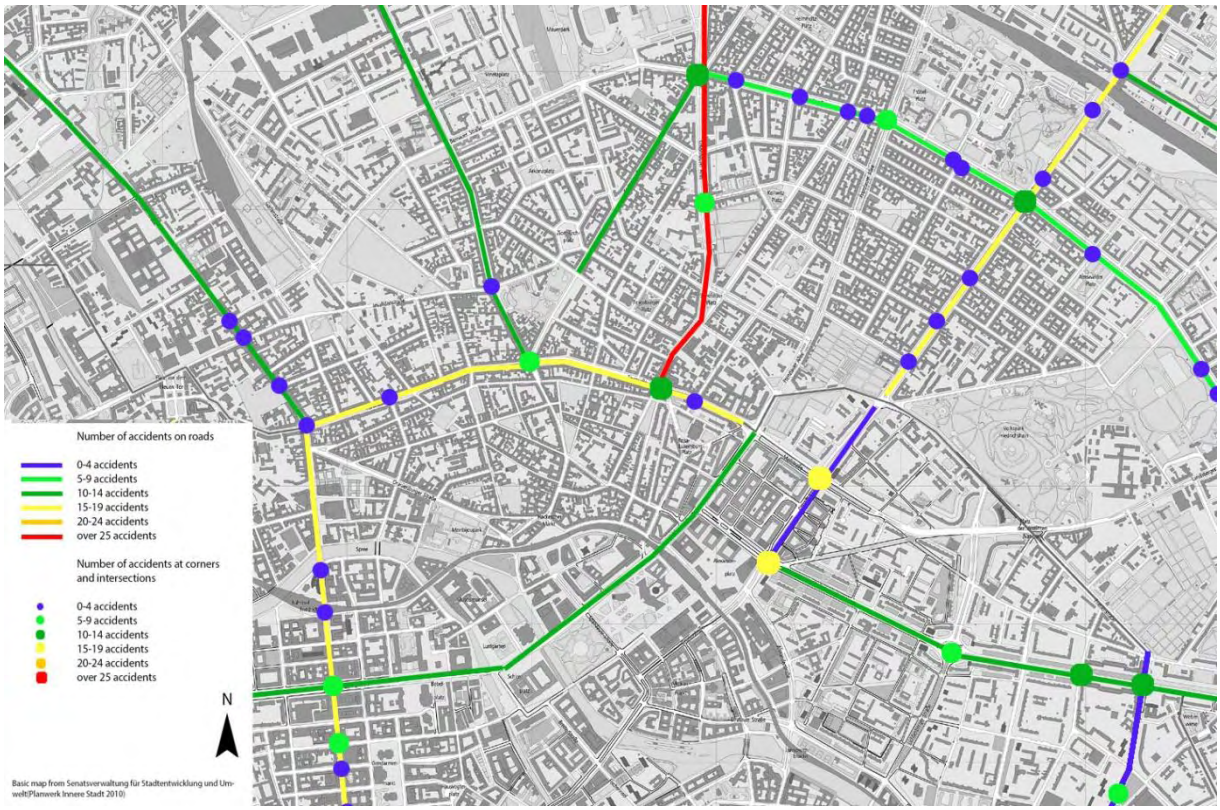


Image 57: Locations with over 10 accidents – detailed view (Own visualization, Base map: Senatsverwaltung für Stadtentwicklung, 2010; Information: Der Polizeipräsident in Berlin, 2012)

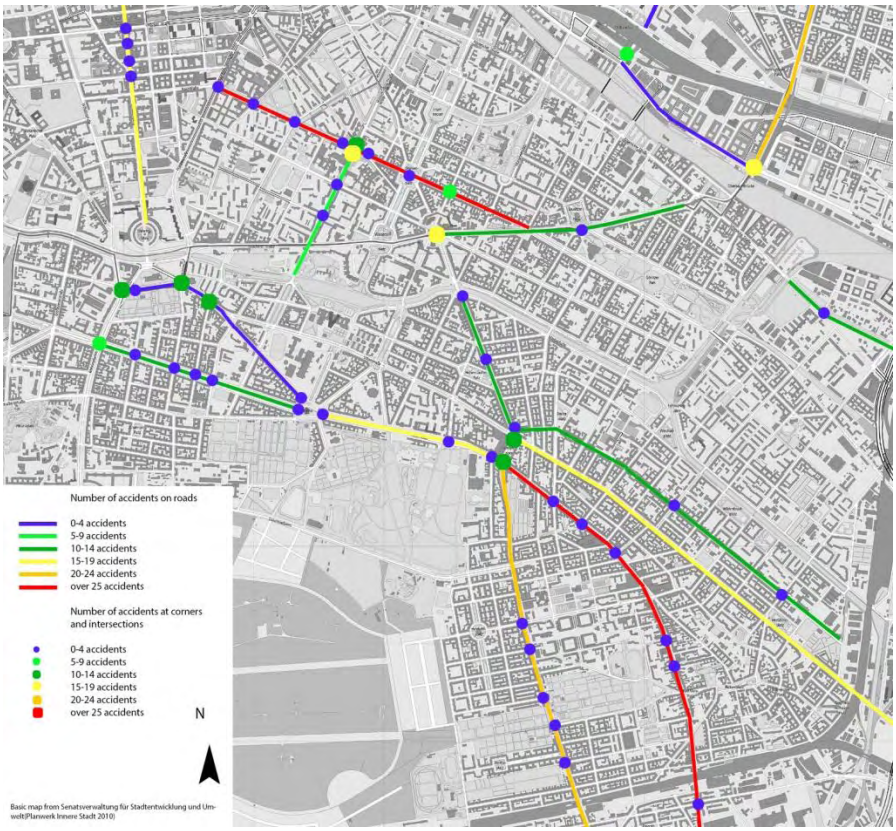


Image 58: Locations with over 10 accidents – detailed view (Own visualization, Base map: Senatsverwaltung für Stadtentwicklung, 2010; Information: Der Polizeipräsident in Berlin, 2012)

The map has limitations, since only instances with 10 or more accidents were noted. The following example, in Alexanderstraße wasn't marked, since none of the locations had individually 10 or more accidents, as it can be seen on the table to the right. In total though there have been 35 accidents at the various corners.

Number of accidents in Alexanderstr. in 2012	
Alexanderstr.	7
Alexanderstr. / Grunerstr.	6
Alexanderstr. / Holzmarktstr. / Stralauer Str.	8
Alexanderstr. / Karl-Liebknechtstr. / Memhardstr.	9
Alexanderstr. / Magazinstr. / Voltairestr.	1
Alexanderstr. / Schicklerstr.	3
Alexanderstr. / Schillingstr.	1
Source: Der Polizeipräsident in Berlin, (2012)	

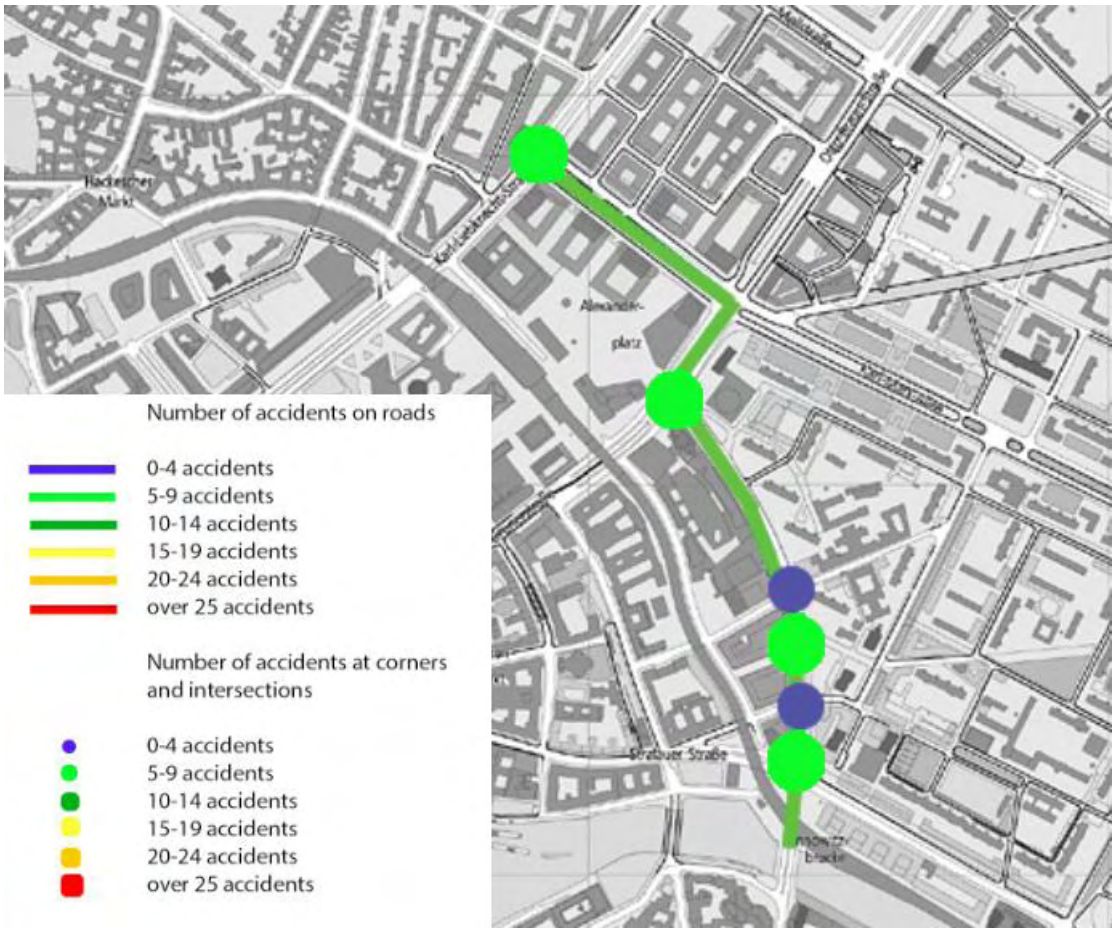


Image 59: Accidents in Alexanderstr. (Own visualization, Base map: Senatsverwaltung für Stadtentwicklung, 2010; Information: Der Polizeipräsident in Berlin, 2012)

5.2 Infrastructure and accidents

There is no correlation between cycling infrastructure and the number of accidents, when purely based on the mapping. Some interesting examples do appear though, when intersecting the two maps.

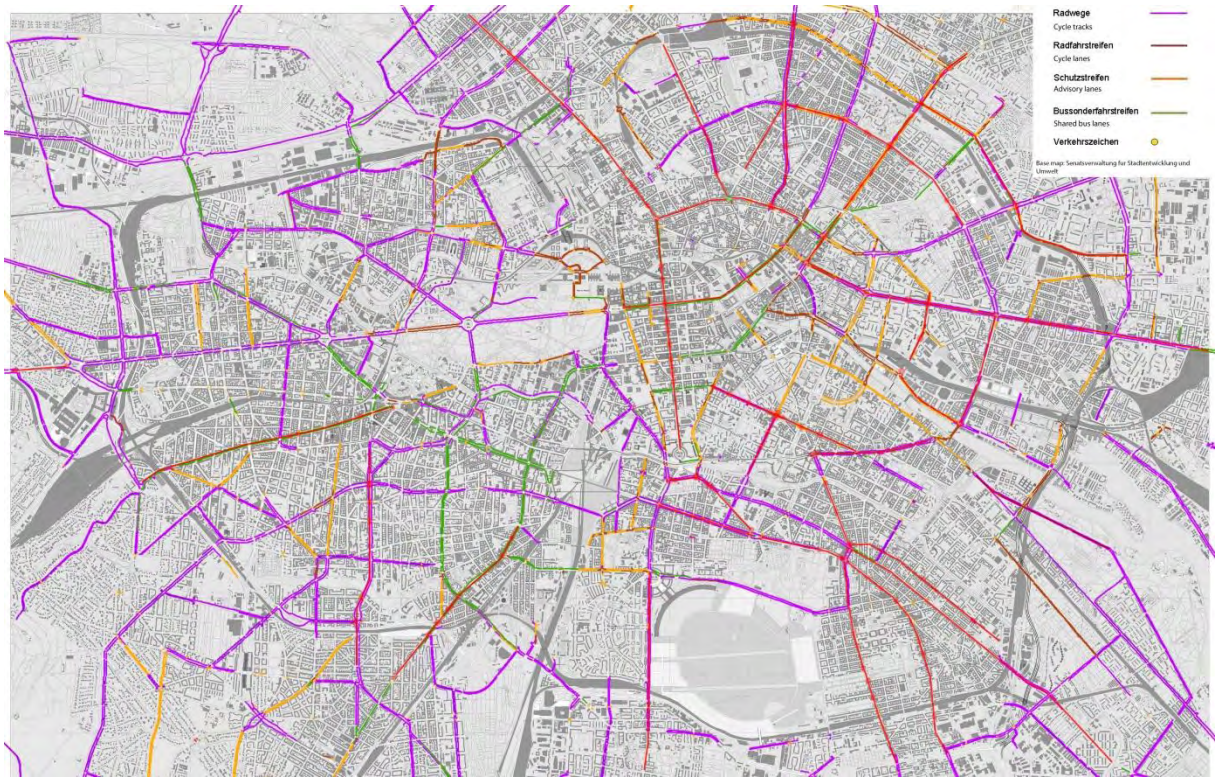


Image 60: Intersecting the cycling infrastructure map with the location of accidents (Senatsverwaltung für Stadtentwicklung, 2010; FIS-Broker, 2013)

For instance the outtake on the right shows the ring road, Bernauer Straße followed by Danziger Straße. As it can be seen, along the purple marked cycle track, there has been no accidents marked (meaning that there hasn't been over ten accidents), while when the cycle track ends, the marking of accidents appear. As already mentioned above, there is no direct overall correlation, except that the most dangerous locations are mainly located in the eastern part of the city.

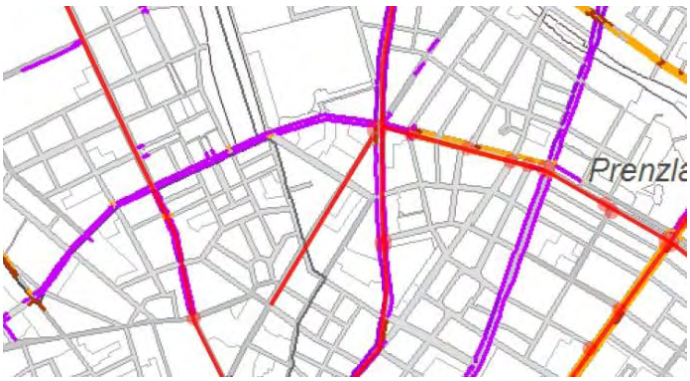


Image 61: Close-up of accidents and infrastructure

5.3 Traffic flow

There is a consensus in Danish experience that good cycling facilities are located on major shopping streets or on roads where they naturally circulate. Directing them in streets parallel to primary roads is not considered a good idea (Andersen et al., 2012). In order to highlight the existing mobility patterns, the following map shows all roads, which have more than 30,000 vehicles on an average day. The traffic flow on the city scale outlines the main arterial roads, which can have potential in moving people from cars to bikes, given the right cycling infrastructure.

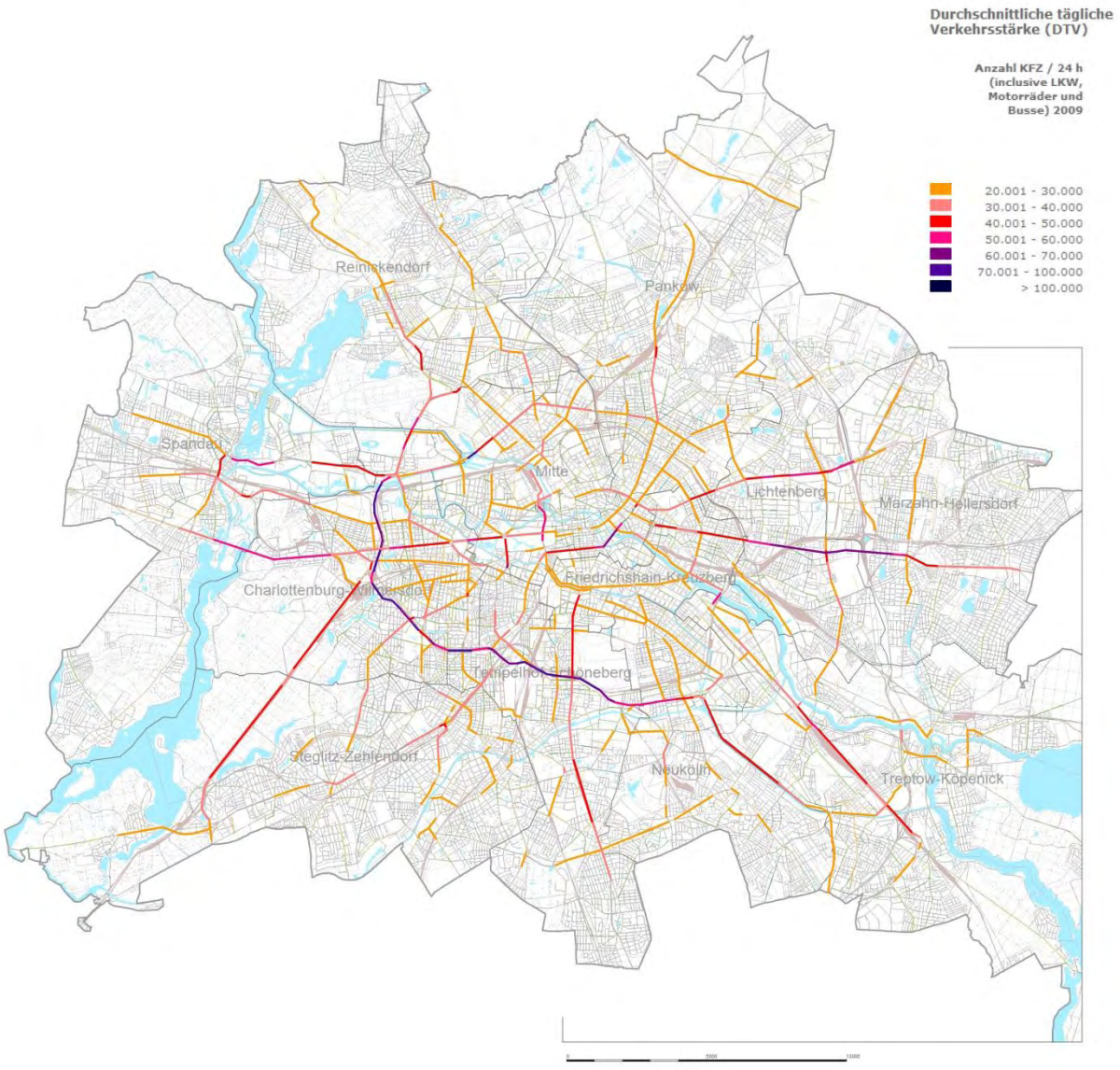


Image 62: Roads with over 20,000 vehicles per day (FIS-Broker, 2013)

For the inner city further streets were marked, the ones with over 10,000 vehicles were also highlighted.

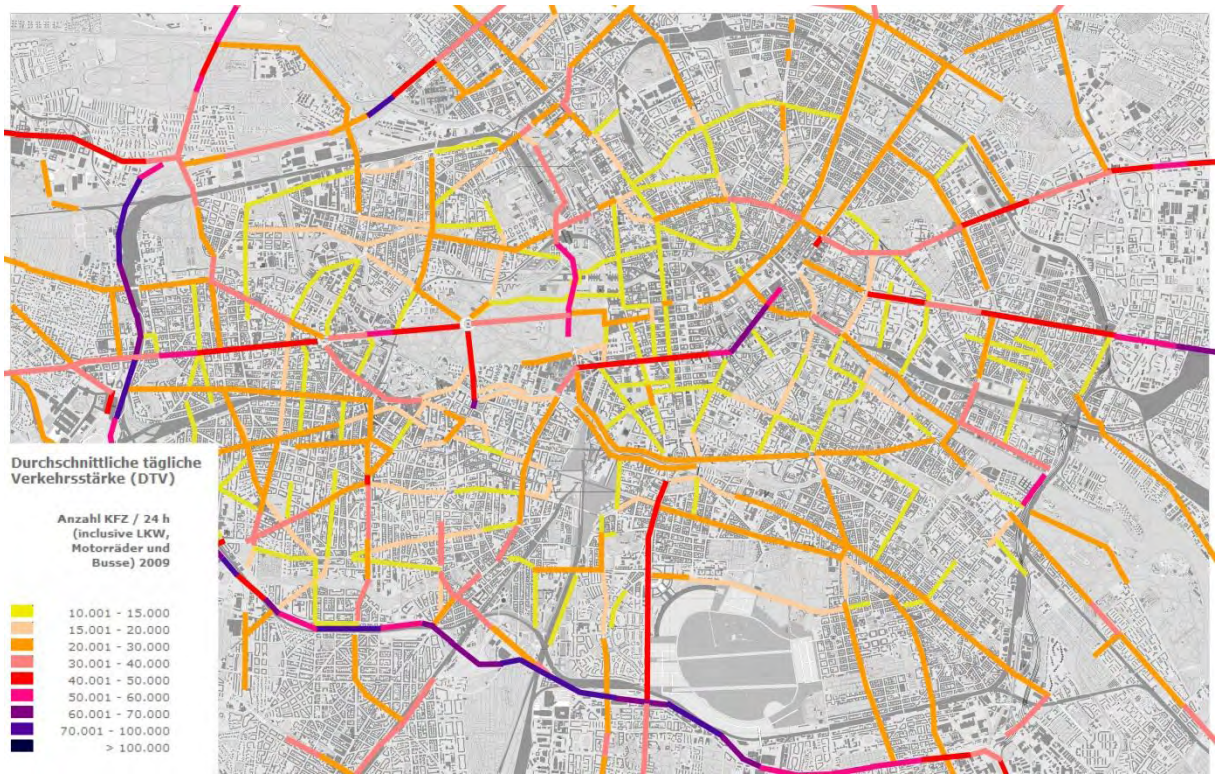


Image 63: Steets with over 10,000 vehicles a day (Senatsverwaltung für Stadtentwicklung, 2010; FIS-Broker, 2013)

5.4 Public Transport

According to the categorization of train stations in Berlin, the top two highest categories, including 12 stations were marked on the following map. These nodes of transport should be well integrated in a cycle network, especially to support intermodality. Although this research does not deal with it in detail, but at these train stations with high user numbers, bicycle parking should be well developed.

Image 64: The biggest train stations in Berlin (FIS-Broker, http://fbinter.stadt-berlin.de/fb/index.jsp; DB Station&Service AG, 2013, own visualization)

On the inner city scale the same map looks like following.

Image 65: Biggest train stations in the inner city (Senatsverwaltung für Stadtentwicklung, 2010; DB Station&Service AG, 2013, own visualizationn)

5.5 Creating the network

The maps created above, were layered, in order to see which roads and nodes need to be connected with cycling infrastructure. First all of the markings on the individual maps were changed to the same colour (details can be seen on the original maps) and then were inserted into a final recommendation. The exact maps which were layered are the ones with information about accidents, urban centres, public transport and traffic flow (Image 54, 55, 60, 66, 67, and 68). There were two maps created, one for the inner city and one for the entire city, which can be seen below.

Image 66: The network of Accidents, Urban centres, Traffic flow and Train stations (Der Polizeipräsident in Berlin, 2012; Senatsverwaltung für Stadtentwicklung, 2011a; FIS-Broker, 2013; DB Station&Service AG, 2013)

Image 67: The network of Accidents, Urban centres, Traffic flow and Train stations in the inner city (Der Polizeipräsident in Berlin, 2012; Senatsverwaltung für Stadtentwicklung, 2011a; FIS-Broker, 2013; DB Station&Service AG, 2013)

6 Conclusions

6.1 Final network recommendation

The network of the two maps has been extended, in order to create a network, without gaps. This leads to the final recommendations, which are the following two maps. A larger version can be found in the Annex (8.5. and 8.6.).

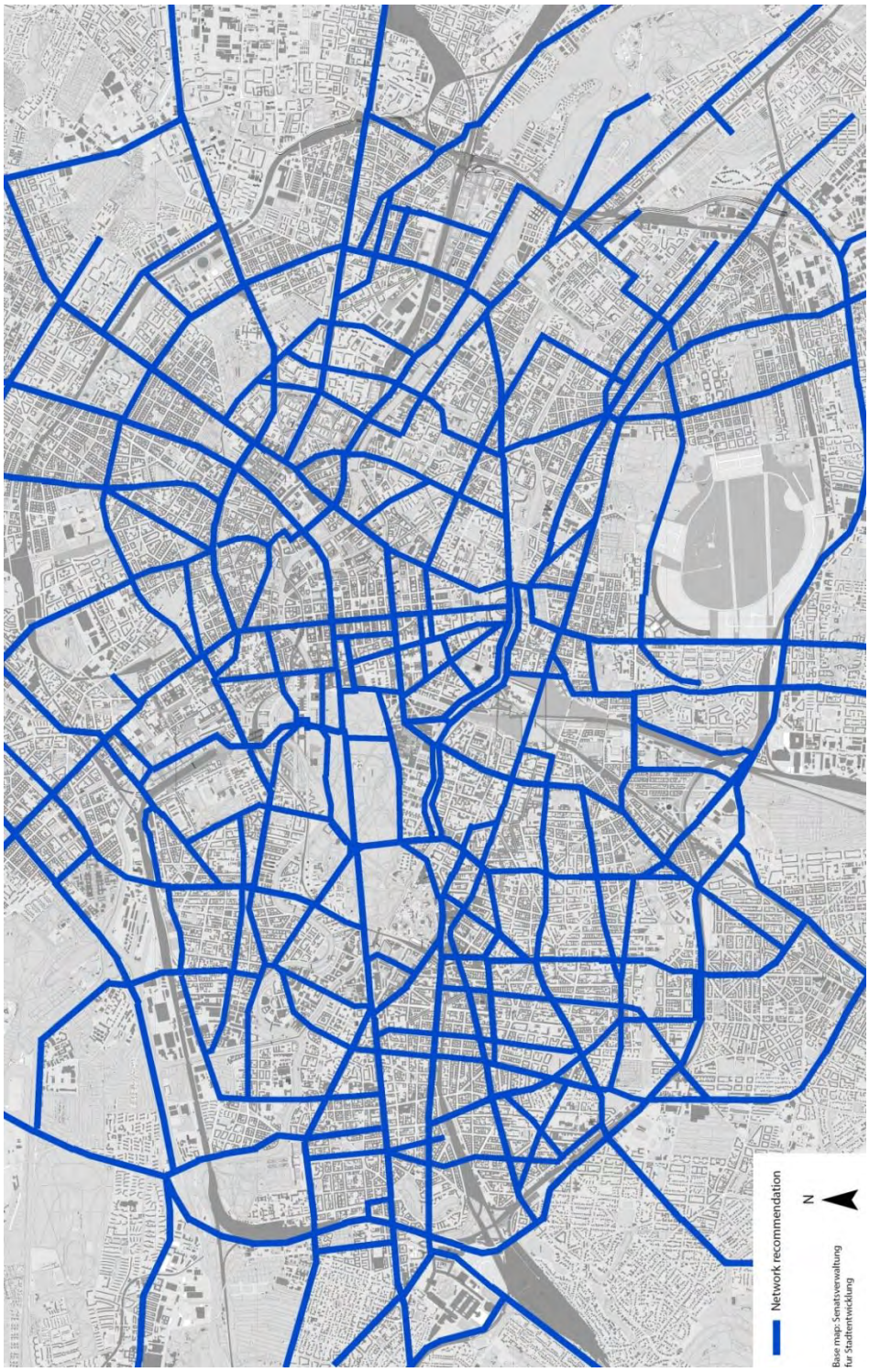


Image 68: Network recommendation for the inner city (Senatsverwaltung für Stadtentwicklung, 2010)

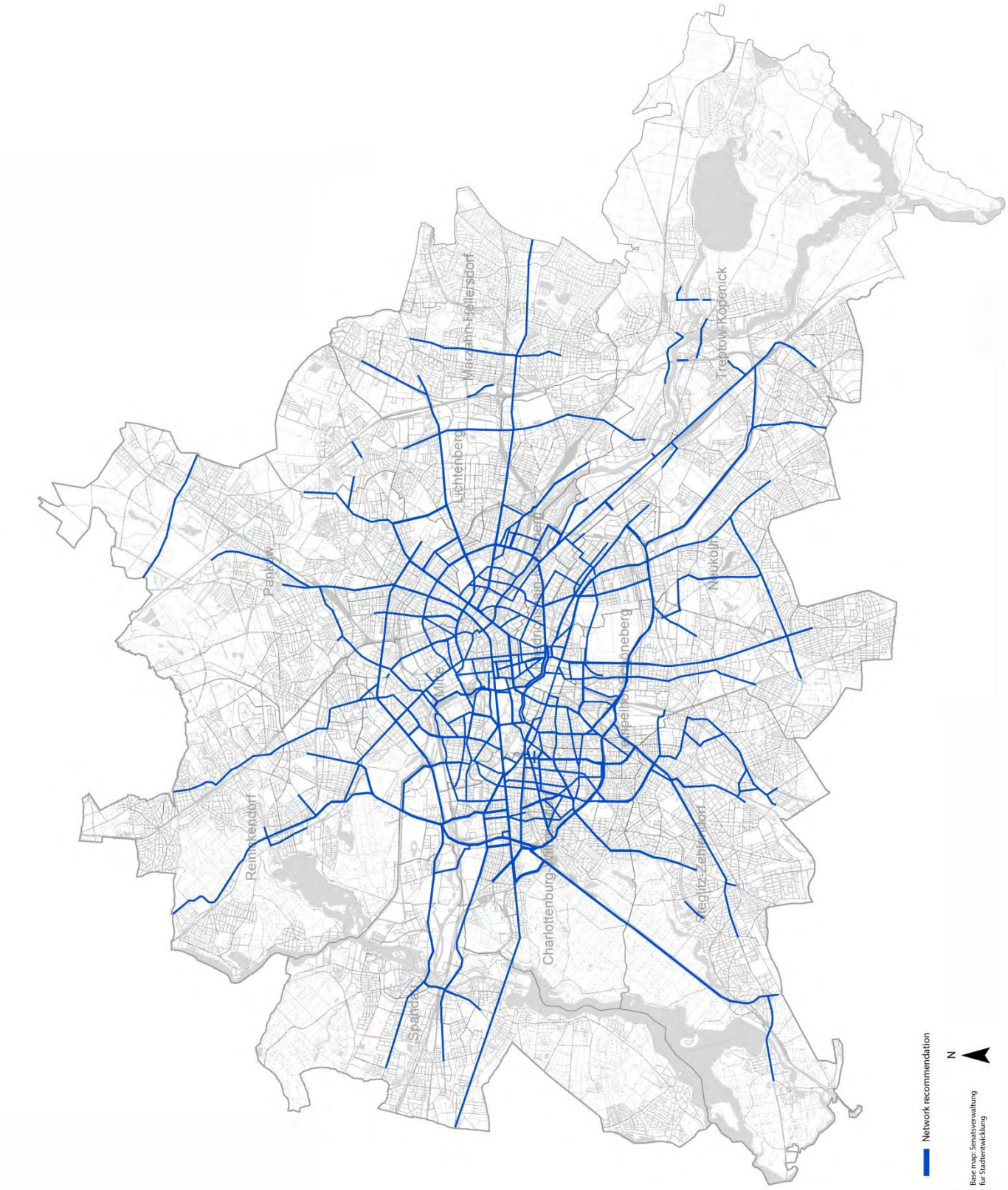


Image 69: Network recommendation for Berlin (FIS-Broker, 2013)

The recommendation developed here is a large scale plan, which means that some of the details are rather rough. For instance the highway is marked as a route, which would need a cycle network. In cases of highways it would be important to see whether a green cycle path could be an alternative, instead of riding close to heavy traffic. Even if a green cycle path is not possible, a secure separation has to be guaranteed.

Since the financial needs for new cycling infrastructure can be straining for a city, it is possible to implement cycle tracks in multiple phases. Cycle lanes can be first installed as temporary solutions, since they are cheaper and be replaced later on for cycle tracks. In order to make this possible the cycle lanes should have the width of the planned cycle track (Dutch Bicycle Council, 2006).

There are many aspects, which can be considered during the planning of cycling infrastructure. Traffic calming measures may make cycle tracks unnecessary, while traffic calmed neighborhoods can connect primary roads with each other. Even on roads, on which there is no need for cycle tracks, there should be enough space for cyclists. A parking garage can remove some on street parking, allowing for more space for cycling infrastructure, while alternate-side parking can also free some road space (Andersen et al., 2012). It is important that each street and intersection are individually planned, since there can be many individual issues that have to be tackled, whether that is avoiding conflicts between the users of cycle tracks and bus stops or simply creating a safe intersection with good visibility.

It should be considered during the planning that the average cycle track width of 2.2 meters in Copenhagen can carry up to 2,300 cyclists (Dutch Bicycle Council, 2006). These measures are often not enough to facilitate rush hour cycle traffic. The width of cycle tracks especially in neighborhoods with high population density should be planned with the consideration that the extension in width should be possible, in case needed.

The choice of surfaces for cycle tracks should be changed to asphalt, since it is in general the most suitable material. Although bicycle streets are not used in Copenhagen, since they have a good acceptance in Berlin, they should be considered as a tool during the planning.

This research is based on top-down planning, researching hard numbers and facts. It should serve as a theoretical contribution to planning, but it is important to point out that the public should be involved intensively along the planning process. Not do they only have hands on information about the issues of cycling infrastructure but the participation can lead to a wider discussion, better education about cycling infrastructure and a wider acceptance towards cycling in general (Andersen et al., 2012).

When comparing the cycle network developed in this research and the existing plan of the city, there are is a rather big difference. There are some routes, which cover each other, but an overwhelming part of it is different. A larger version of the map can be found in the Annex (8.4.). Many of the arterial roads, which were highlighted during this research, due to the amount of traffic, are not included in the plans of Berlin. Instead of covering the arterial roads with cycling infrastructure, parallel roads are marked for the routes. This also means, that many of the streets which I marked because of the many cycling accidents, are not part of the network plan of Berlin.

Image 70: Comparison of Berlins planned cycle network an my network recommendation (Senatsverwaltung für Stadtentwicklung und Umwelt, 2013b)

6.2 Other conclusions

The analysis shows that Berlin has both positive and negative qualities when it comes to the cycling infrastructure. Starting with the potentials of the city, they have in an international comparison a relatively high share of cyclists, in some areas even reaching 21%, while having a relatively low car ownership rate. In Comparison to the 35% cycle share of Copenhagen it is still low. The growing bicycle share in Berlin over the years indicates that there is an interest and willingness of inhabitants to cycle. The city has a long network of cycling infrastructure, which has already been built and can be a potential for later developments. Then again in comparison to Copenhagen, which has 80 km of cycling infrastructure per 100,000 inhabitants, Berlin only has 33 km. Further the city has a well-developed and well used public transportation system, which if integrated with the cycling network could enhance cycling.

On the other hand though, the existing cycling infrastructure in Berlin has many flaws. There are many issues with the surface of the cycle tracks, which is due to both the chosen surface material and the lack of maintenance. The rough surfaces are often combined with flawed design that does not offer safety for neither pedestrians, cyclists nor cars. The design is often outdated or was flawed to begin with. There is also no unified design for cycling infrastructure, which would make cycling more intuitive. There are also issues with guaranteeing that cycling infrastructure are free from obstacles, which are in most cases parked vehicles on cycling infrastructure. In Berlin there is an interesting stand in the debate on cycling infrastructure. There is no consensus about the type of cycling infrastructure, which is needed. Many groups actively involved with cycling tend to promote

on road cycling instead of separated cycle tracks. This approach is not in line with that of Copenhagen, according to which on-road facilities do not attract traffic sensitive riders. A consensus and a better education on the topic could help achieve better public support.

Returning to the research question posed at the beginning of the research, which was following: How would the city of Berlin develop their cycling infrastructure when following the guidelines of the city of Copenhagen? The map developed shows the basic structure of a cycling network, which would follow the guidelines of the Copenhagen cycling infrastructure. The key concept behind the network is to develop cycle tracks on the busy arterial roads leading into the city, creating a safe environment for commuters to cycle. Moreover this network should be well connected, without gaps in the cycle tracks and connect main destinations of cyclists, whether those are work places, schools, or consumption places. Local streets, which have a low traffic count, can be used as supplementary connections between the cycle tracks, offering low stress cycle environments.

Even if a cycling plan is implemented in phases, it is important to have the aims defined so that all the measures support the same outcome. Public participation should be a basic element of planning. The survey carried out during this research showed that cyclists themselves are a great source of information in defining issues with the cycling infrastructure. Better monitoring, similar to that of the Bicycle account in Copenhagen would help outline the most pressing issues, while provide a form of public participation.

While infrastructure plays a big role in the development of cycling, it is important to point out that all the other factors discussed in this research, such as safe and sufficient parking facilities, integrated planning at all administrative levels and financial security, etc. play an essential role as well. In the end the cycling network has to be intuitive, user friendly and cover all main destinations, while making cycling a choice people make because it is fast, safe and comfortable.

This research is aimed at reflecting the experience of Copenhagen on Berlin. This means that the views on how to “correctly” develop a cycling infrastructure is defined by the experience in Copenhagen. This does not mean however that a different approach is not possible or not correct. For this reason the discussion about the approach should be open to everyone and open to new solutions.

6.2.1 Further research

Further research would be interesting in multiple fields. It would be interesting to make a further analysis about the arterial roads, in order to define, which roads are most suitable to develop cycle super highways, guaranteeing a fast and safe connection to the city center. It would also be interesting to analyze locations where new connections could be created. Since the network

recommendation in this study was based to a large extent on existing traffic flows on roads, routes through parks were not included, although they can have a large potential.

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7.1 Table of images

7.1 Table of Graphs

8 Annex

8.1 Survey

A survey was developed and carried out, involving over 400 participants, rating the satisfaction of users with the cycling infrastructure in Berlin. The questions of the survey were developed based on the biannual survey carried out in Copenhagen. The survey could be accessed online and was distributed by groups on social media, who are involved with cycling or have some cycling interests. Since the participants weren't directly addressed there is no response rate. The survey design and the detailed results of the survey are on the following pages.

8.1.1 Survey design

Rating cycling facilities in Berlin

Thank you for taking the time to fill out my survey!
The aim of the questionnaire is to measure how cyclists rate the existing cycling infrastructure in Berlin, in order to improve it. Answering the questions takes about 2 minutes.
Thank you again!

1. Gender

Male

Female

2. Age

<16

16-25

26-35

36-45

46-55

56-65

66-75

76<

3. Do you own a bike?

Yes

No

4. How often do you use your bike?

Multiple times a week

Around once a week

Around once a month

Few times a year

Other

5. How safe do you perceive cycling in Berlin on a scale of 1 to 5? (1 being "Not safe at all", 5 being "Very safe")

1 2 3 4 5

6. How satisfied are you with the amount of cycle lanes and cycle tracks on a scale of 1 to 5? (1 being "Not satisfied at all", 5 being "Very satisfied")

Hint: Cycle lanes are on-road cycling facilites, with painted markings, while cycle tracks are separated from road traffic, usually by being elevated.

1 2 3 4 5

7. How satisfied are you with the width of the cycle lanes and tracks on a scale of 1 to 5? (1 being "Not satisfied at all", 5 being "Very satisfied")

1 2 3 4 5

8. How satisfied are you with the maintenance of cycling lanes and tracks on a scale of 1 to 5? (1 being "Not satisfied at all", 5 being "Very satisfied")

1 2 3 4 5

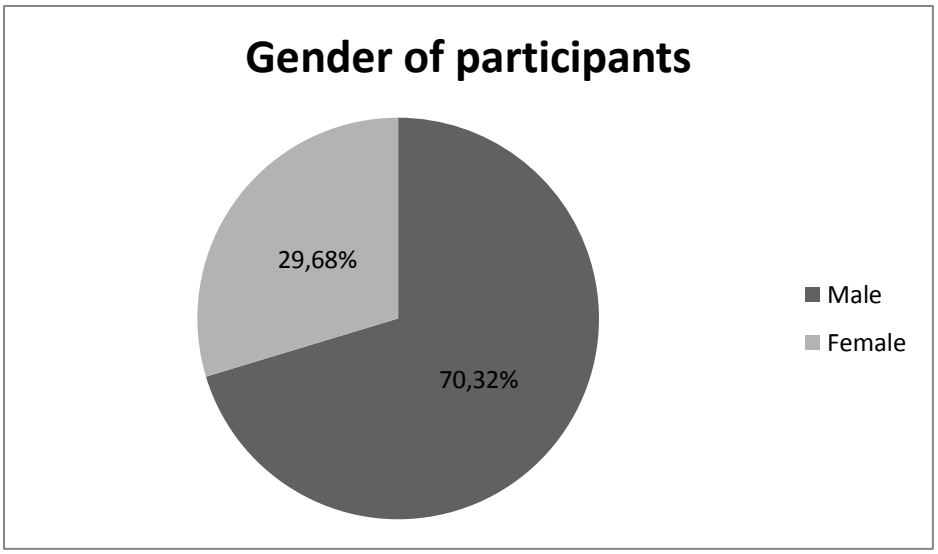
9. How satisfied are you generally with cycle parking facilities on a scale of 1 to 5? (1 being "Not satisfied at all", 5 being "Very satisfied")

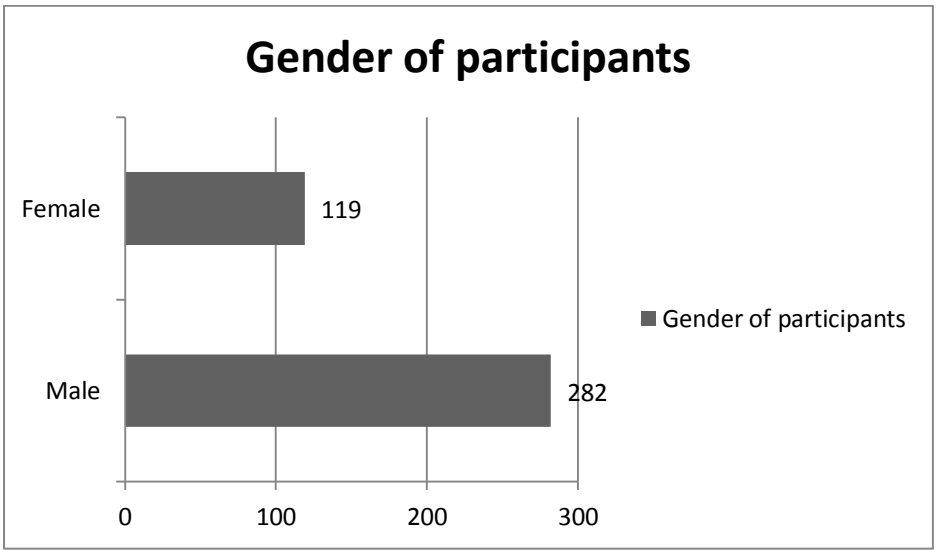
1 2 3 4 1

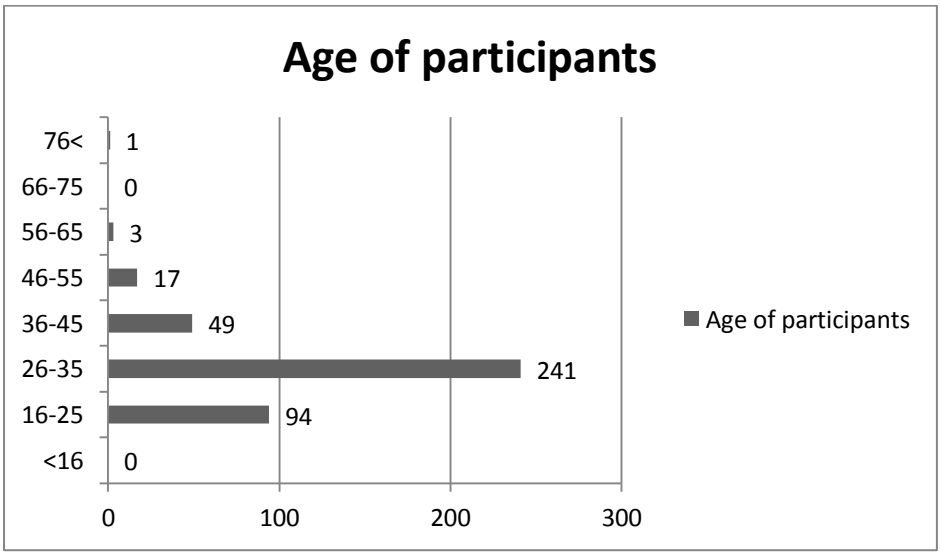
10. What would make you cycle more? Any suggestions are welcome!

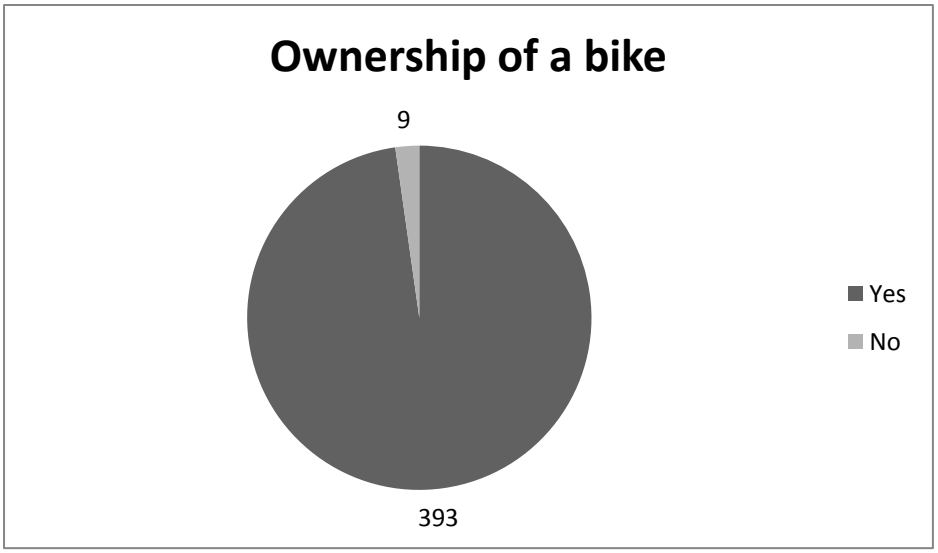
Færdig

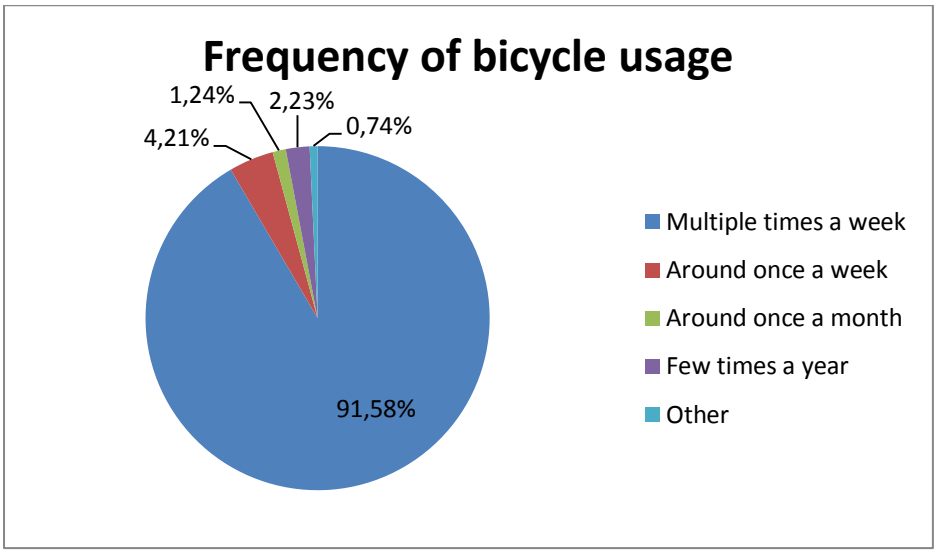
8.1.2 Survey results

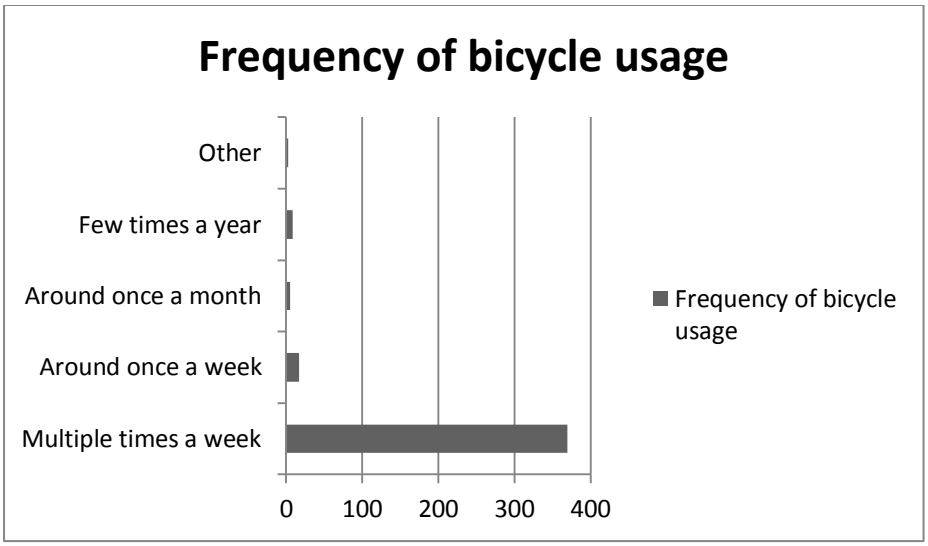


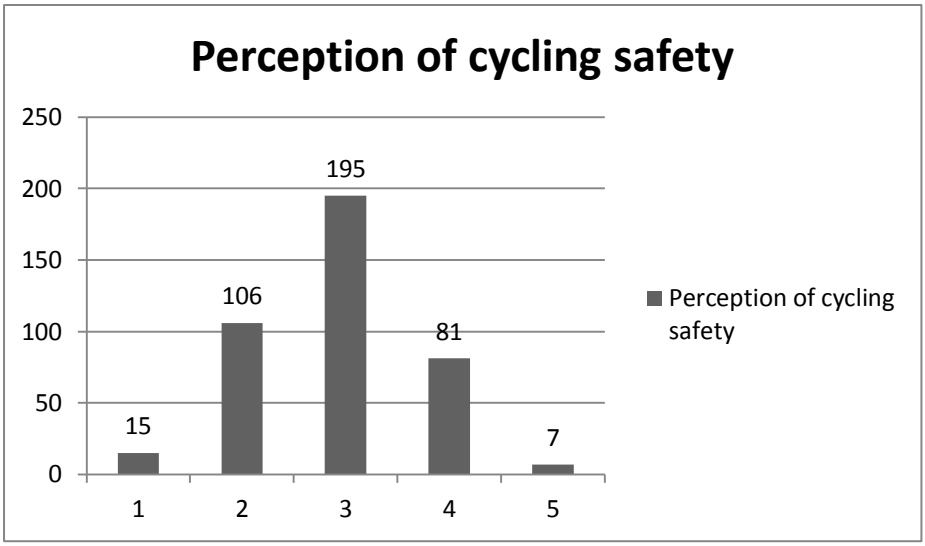


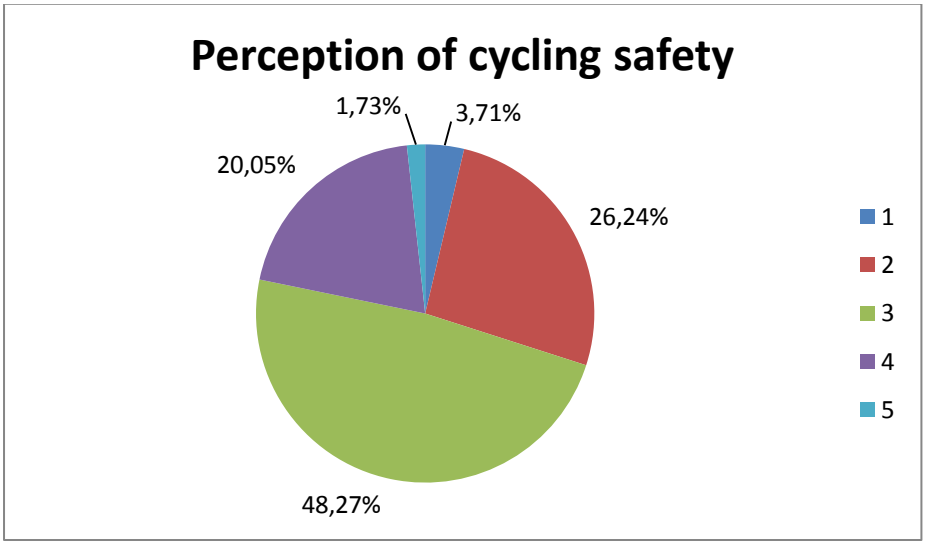


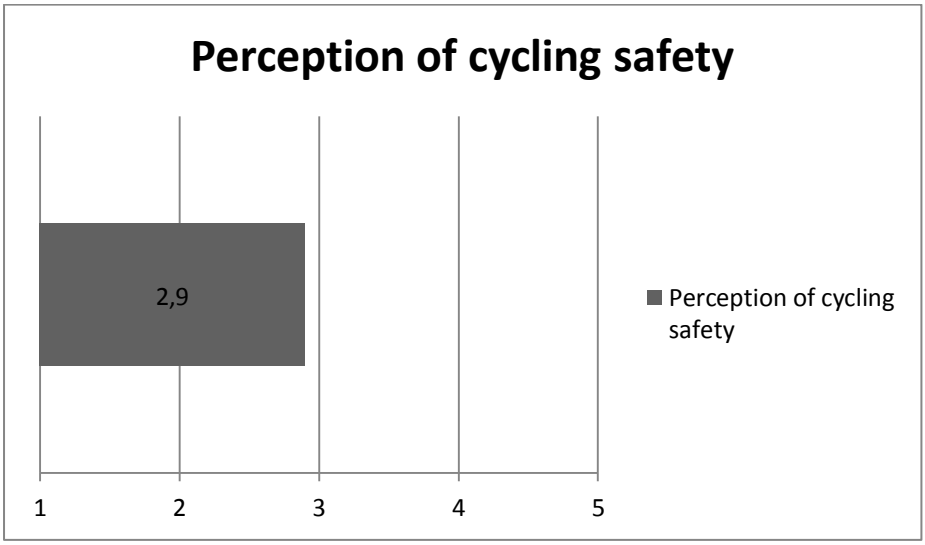

Ownership of a bike
9
393
Yes
No

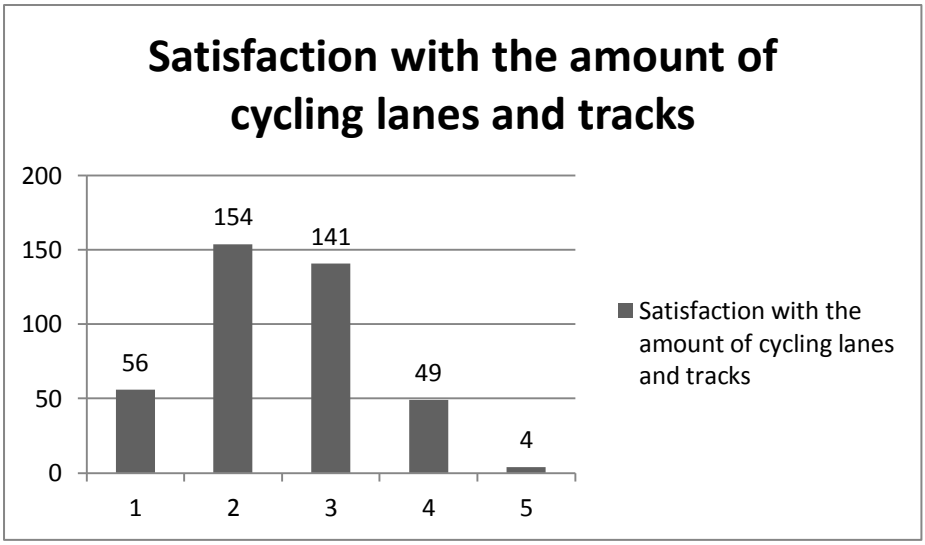

Frequency of bicycle usage
1,24%
2,23%
0,74%
4,21%
91,58%
Multiple times a week
Around once a week
Around once a month
Few times a year
Other

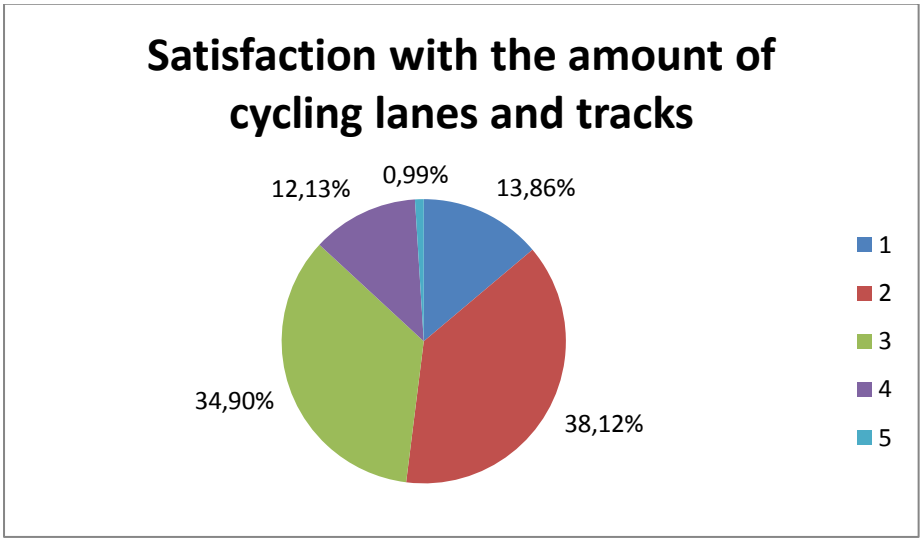

Frequency of bicycle usage
Other
Few times a year
Around once a month
Around once a week
Multiple times a week
0
100
200
300
400
Frequency of bicycle usage

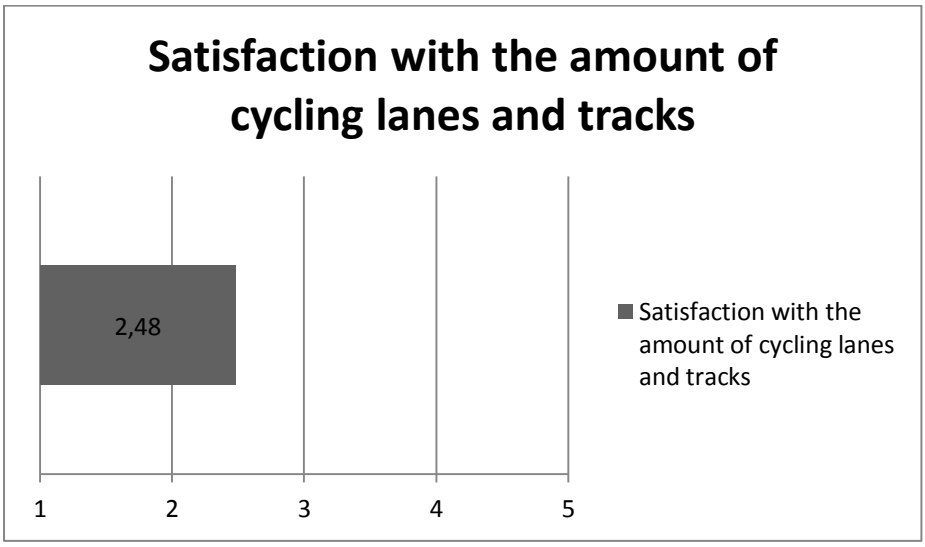

Perception of cycling safety
250
200
150
100
50
0
195
106
81
15
7
1
2
3
4
5
Perception of cycling safety

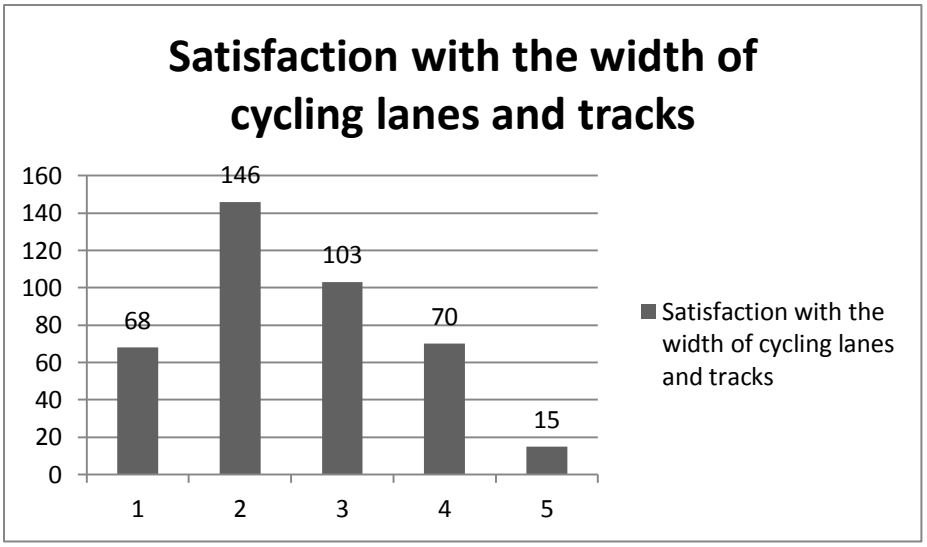

Perception of cycling safety
1,73%
3,71%
20,05%
26,24%
48,27%
1
2
3
4
5

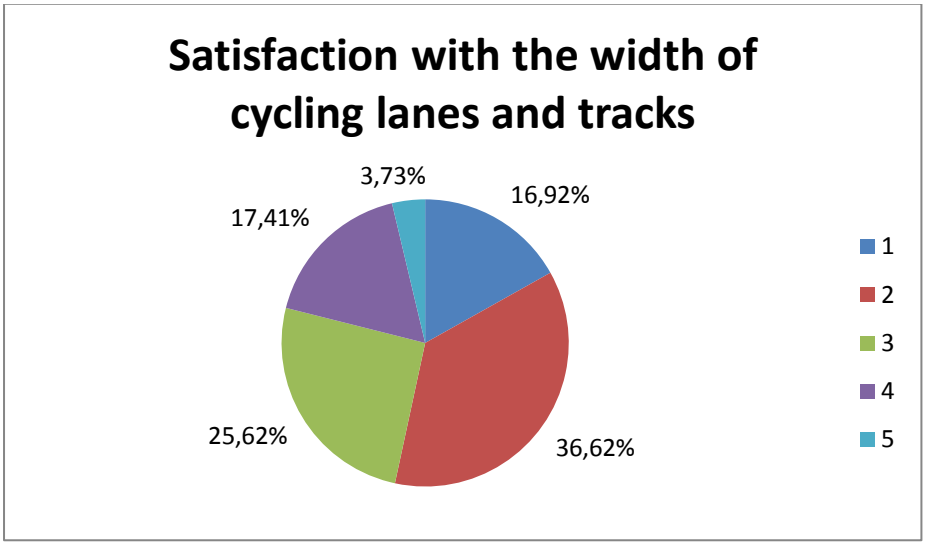

Perception of cycling safety
2,9
1
2
3
4
5
Perception of cycling safety

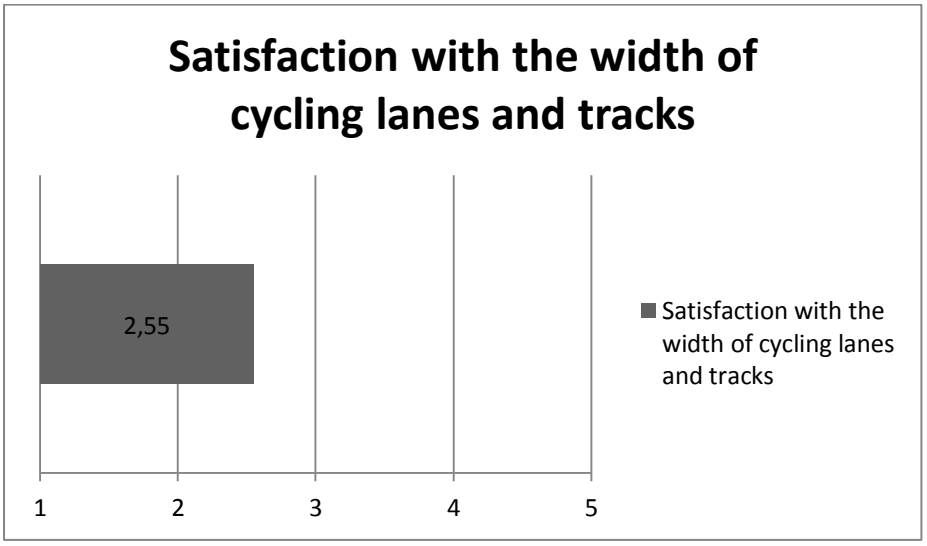

Satisfaction with the amount of cycling lanes and tracks
200
150
100
50
0
154
141
56
49
4
1
2
3
4
5
Satisfaction with the amount of cycling lanes and tracks

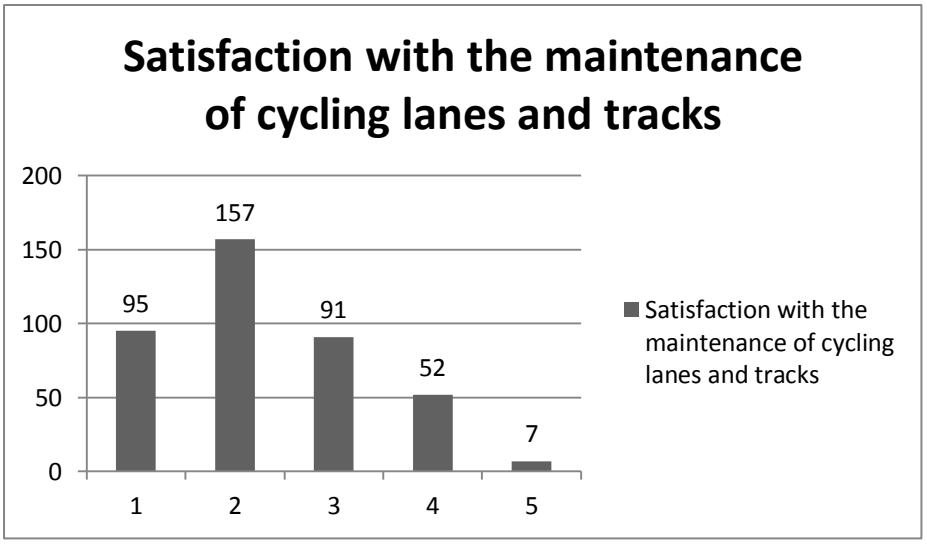

Satisfaction with the amount of cycling lanes and tracks
0,99%
12,13%
13,86%
34,90%
38,12%
1
2
3
4
5

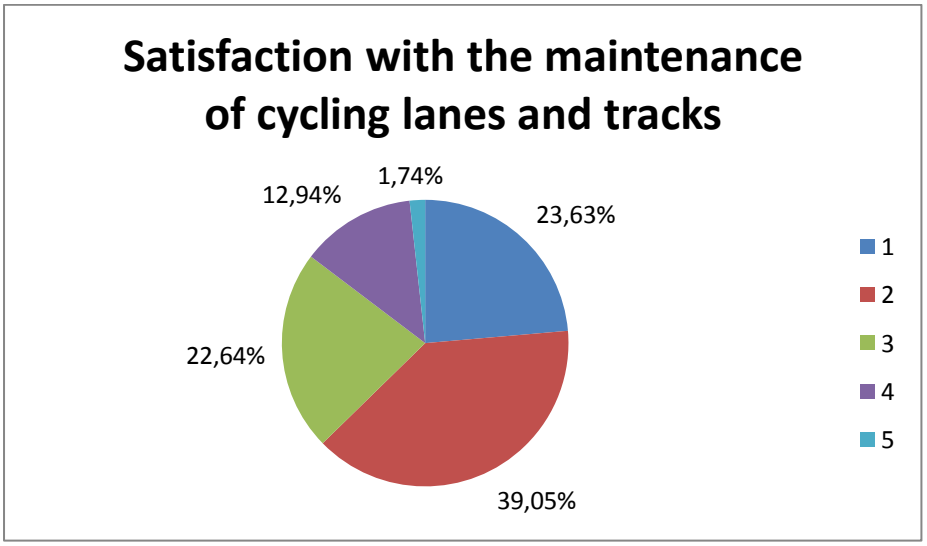

Satisfaction with the amount of cycling lanes and tracks
2,48
1
2
3
4
5
Satisfaction with the amount of cycling lanes and tracks

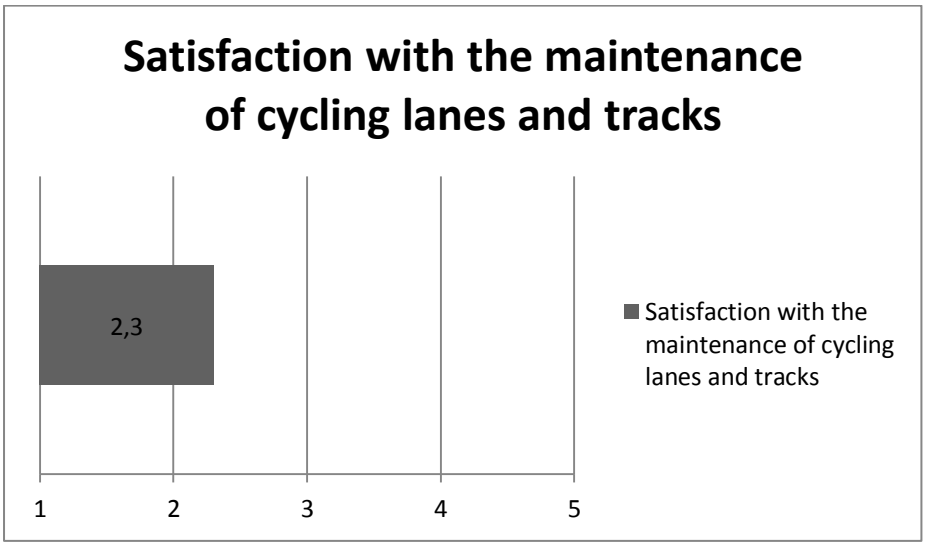

Satisfaction with the width of cycling lanes and tracks
160
140
120
100
80
60
40
20
0
146
103
68
70
15
1
2
3
4
5
Satisfaction with the width of cycling lanes and tracks

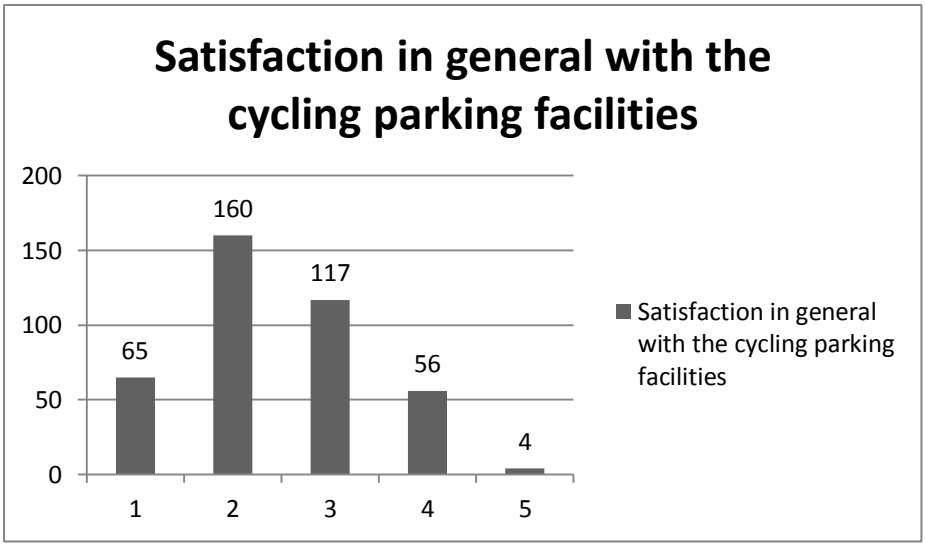

Satisfaction with the width of cycling lanes and tracks
3,73%
16,92%
17,41%
25,62%
36,62%
1
2
3
4
5

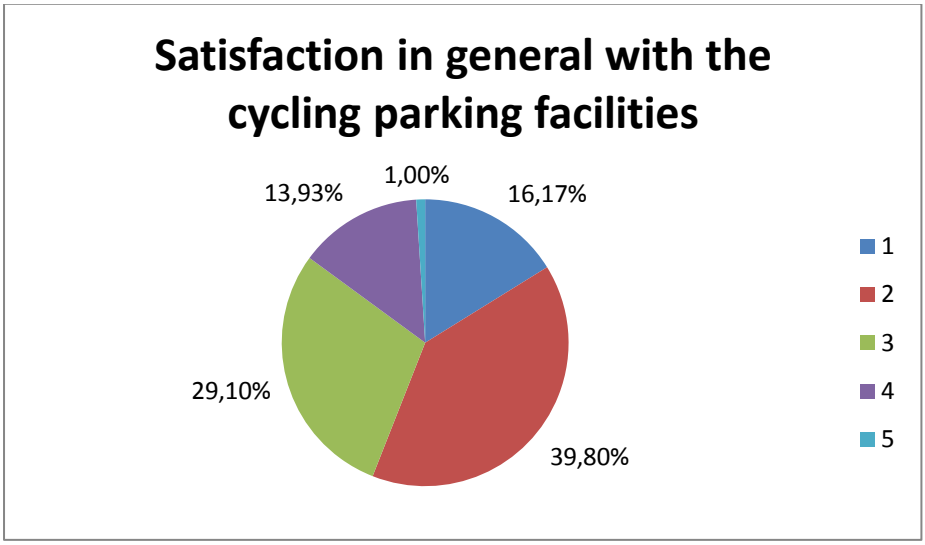

Satisfaction with the width of cycling lanes and tracks
2,55
1
2
3
4
5
Satisfaction with the width of cycling lanes and tracks

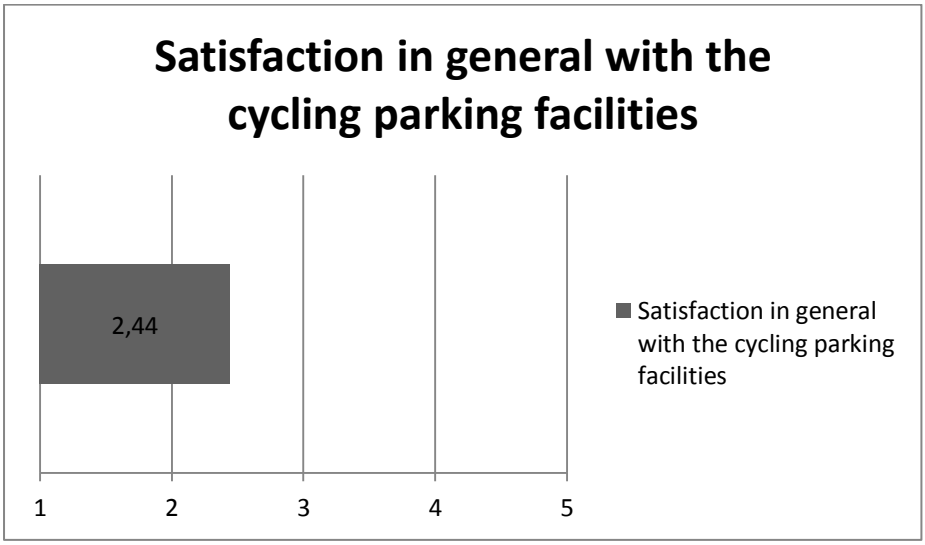

Satisfaction with the maintenance of cycling lanes and tracks
200
150
100
50
0
95
157
91
52
7
1
2
3
4
5
Satisfaction with the maintenance of cycling lanes and tracks


Satisfaction with the maintenance of cycling lanes and tracks
1,74%
12,94%
23,63%
22,64%
39,05%
1
2
3
4
5

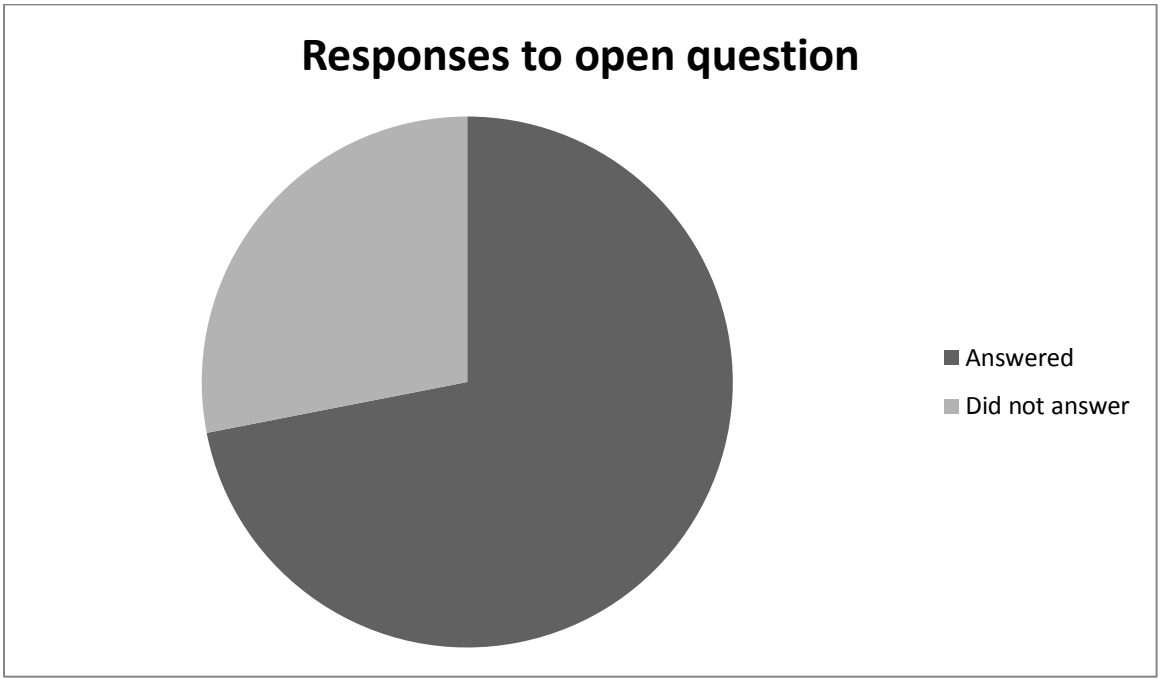

Satisfaction with the maintenance of cycling lanes and tracks
2,3
1
2
3
4
5
Satisfaction with the maintenance of cycling lanes and tracks


Satisfaction in general with the cycling parking facilities
200
150
100
50
0
65
160
117
56
4
1
2
3
4
5
Satisfaction in general with the cycling parking facilities

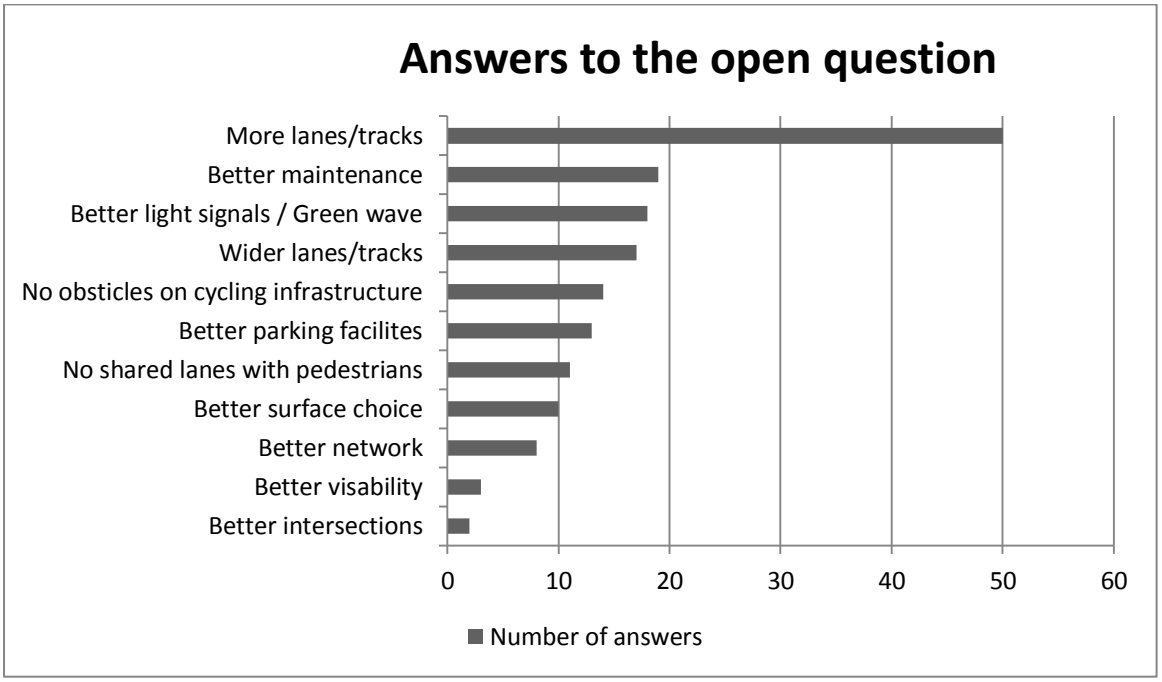

Satisfaction in general with the cycling parking facilities
1,00%
13,93%
16,17%
29,10%
39,80%
1
2
3
4
5

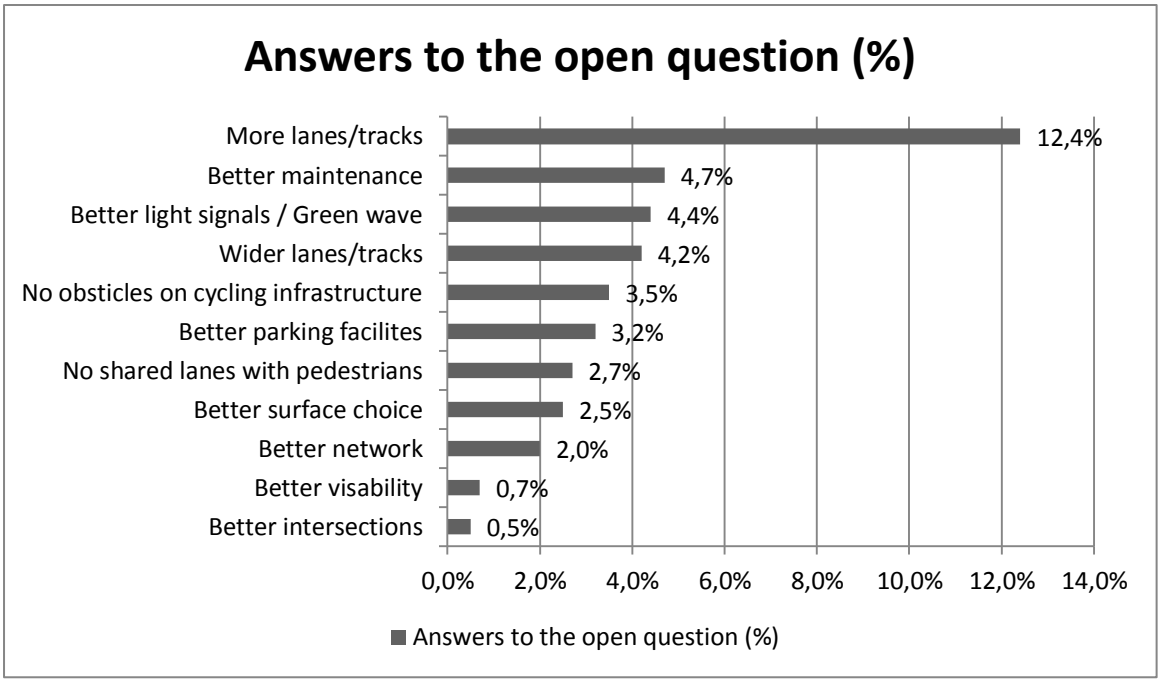

Satisfaction in general with the cycling parking facilities
2,44
1
2
3
4
5
Satisfaction in general with the cycling parking facilities

What would make you cycle more?



Of the 405 participants 201 chose to answer the last open question, which asked “What would make you cycle more? Any suggestions are welcome!”




Answers to the open question (%)
More lanes/tracks
Better maintenance
Better light signals / Green wave
Wider lanes/tracks
No obsticles on cycling infrastructure
Better parking facilites
No shared lanes with pedestrians
Better surface choice
Better network
Better visability
Better intersections
12,4%
4,7%
4,4%
4,2%
3,5%
3,2%
2,7%
2,5%
2,0%
0,7%
0,5%
0,0% 2,0% 4,0% 6,0% 8,0% 10,0% 12,0% 14,0%
Answers to the open question (%)

8.2 Interview Results

8.2.1 Interview with Niels Jensen

Following is the interview with Niels Jensen , who is working for the traffic department in the Technical- and Environmental Administration of Copenhagen.

1.How would you describe the essential guidelines of the development of cycling infrastructure in Copenhagen?

Concerning guidelines, we have politically approved plans for the various kinds of cycling infrastructure:

- Cycle tracks along major roads (priority plan)
- Green cycle routes (with priorities)
- Cycle super highways/commuter routes (in cooperation with suburbs)

2.What do you think is the biggest lack in the current cycling infrastructure in Copenhagen?

Biggest lack is, I think, to improve the cycle tracks along the most busy major roads to reach the PLUS net standard described in the Cycling strategy. We also still have to establish a few cycle tracks along major roads. As well as many of the green cycle routes. And we have just started with establishing cycle super highways.

3. How would you describe the cooperation of different agents (including government, policy makers, technical department, citizen engagement, etc.) in developing cycling infrastructure? What aspects do you think need improvement?

The City of Copenhagen is very independent when it comes to planning cycling infrastructure. Basically, financing is also up to the city, but recent years it has been possible to get some support from the national government to establish infrastructure which could be of common interest in the development of Danish cycling infrastructure. There is now also a special governmental funding to help municipalities to establish Cycle super highways. Concerning the cooperation in developing Copenhagen cycling infrastructure, I think it is pretty difficult to describe. Years ago the planning was primarily driven by the civil servants in the Road Department, more recently, politicians has played a major role, e.g. when it comes to goals like in the Cycling strategy. – And of course funding. The citizens also have a role, suggesting various improvements of the cycling infrastructure. I think we

have a good process with the political level when it comes to the yearly budget for cycling infrastructure.

4. What causes the most difficulties in the process of developing cycling infrastructure?

Although we get quite good funding for cycling infrastructure, we could easily use much more to bring cycling to a higher level. A good example is the Cycle super highways, which could help to get more commuters cycling. We have by now only two routes, if you want car drivers in general to choose to cycle, you need many more routes pretty soon.

5.What do you think is the most important factor to get people to cycle?

I think some kind of road pricing combined with better infrastructure for cycling is crucial to reach our goal of 50% commuters on bike to work and education situated within Copenhagen borders.

6.Why do you think Copenhagen (and Denmark in general) could develop such a high modal share of cyclists?

I think the high modal share has a lot to do with tradition and cycling infrastructure which has been in place for many years. In cities like Copenhagen, cycling is competitive with other means of transport – speed and convenience.

7.What do you think, are the most important aspects of your cycling infrastructure, which other cities should apply, in order to achieve a higher modal share of cyclists?

I think it is important to install cycle tracks along major roads. In Copenhagen, the cyclist were already there, so when a new cycle track was established, it was in use from day one. This may be different in cities with no cycling tradition, so it is a longer discussion how you get started.

8.2.2 Interview with Martin Schlegel

Following is the interview with Martin Schlegel traffic referent of the BUND Berlin

1.How would you describe the essential guidelines of the development of cycling infrastructure in Berlin? (Wie würden Sie die wesentlichen Richtlinien der Entwicklung der Fahrradinfrastruktur in Berlin beschreiben?)

Im StEP Verkehr wurde 2002 die Erarbeitung eines „Berliner Radverkehrsplans“ ist den neuen Handlungsfelder bereits festgelegt: Velorouten mit Wegweisung, Grüne Wege und Abstellmöglichkeiten.“ Dafür wurde ein „Fahrrat“ ins Leben gerufen, dessen Mitglieder alle das Ziel einte, den Radverkehr in Berlin zu fördern. Wichtigste Maßnahmen,die in der ersten Radverkehrsstrategie 2006 beschlossen wurden, waren das Radspurenprogramm sowie weitere Haushaltsposten für den Radverkehr. BVG und S-Bahn versprachen, deutlich mehr Fahrradbügel aufzustellen. Durch den schnell wachsenden Radverkehr wird die Planung wieder vor neue Aufgaben gestellt. Ziel ist es jetzt, die Infrastruktur an den wachsenden und schneller werdenden Radverkehr anzupassen.

Der ADFC und der BUND begrüßten es daher, dass die neue Radverkehrsstrategie endlich beschlossen wurde. Diese setzt mit den Themen Kapazitätserweiterung, Verkehrssicherheit und Fahrradparken die richtigen Schwerpunkte.

English translation:

The new fields of action were defined in 2002 in the “StEP Verkehr” (tranls. Urban development plan for transportation) in which the Berlin Cylcing plan was developed: veloroutes with signage, green cycle routes and parking facilities. For this reason “FahrRat” was launched, in which all members are working in order to promote cycling in Berlin. The most important measure defined in the first Cycle Strategy Plan in 2006 was the Cycle infrastructure plan as well as further budget items for cycle traffic. BVG and S-Bahn have promised to add many more cycle stands. However, due to the rapidly growing cycling; the planning will be facing new challenges. The aim now is to adapt the current infrastructure to the growing cycling traffic and the higher cycling speeds.

Both ADFC and the BUND welcomed the fact that the new Cycling Strategy was decided on. This sets the right priorities with the topics capacity expansion, traffic safety and bicycle parking.

2.What do you think is the biggest lack in the current cycling infrastructure in Berlin? (Was halten Sie als größter Mangel der Fahrradinfrastruktur in Berlin?)

Bei dem ADFC-Fahrradklimatest hat Berlin nur mittelmäßig abgeschnitten. Viele Radelnde ärgern sich nicht nur über die aggressive Fahrweise der Autos sondern auch über die unzureichende Kontrolle bei zugeparkten Radstreifen und –wegen. Während in vielen Medien immer wieder das Thema „Rüpelradler" das Sommerloch füllt, zeigen die tatsächlichen Unfallzahlen den Radfahrer vor allem als Unfallopfer – in der Mehrzahl von rechtsabbiegenden LKW.

English translation:

At the ADFC-cycle-atmosphere-test, Berlin finished mediocre. Many cyclists are angry about both the aggressive driving style of cars but also the lack of control when it comes to ccle lanes or tracks being blocked by parked cars. While in the media the talk is often about "bully cyclists", the accident numbers show that above all the victims –overwhelmingly trucks turning right.

3.How would you describe the cooperation of different agents (including government, policy makers, technical department, citizen engagement, etc.) in developing cycling infrastructure? What aspects do you think need improvement? (Wie würden Sie die Zusammenarbeit verschiedener Akteuren (Regierung, verschiedene Ebenen der Politik, technische Abteilungen, Bürgerbeteiligung, etc.) bei der Entwicklung der Fahrradinfrastruktur beschreiben? Was bräuchte Verbesserungen?)

Der Berliner "Fahhrat" als Instrument der Verbandsbeteiligung funktioniert sehr gut, weil dort nur Aktuere mitwirken, die den Radverkehr fördern möchten. Die Bürgerbeteiligung ist aber aucf jeden Fall noch zu verbessern.

Mit Sorgwe sieht der BUND z.Zt. die Sparmaßnahmen beim Personal in der für Verkehr zuständigen Senatsverwaltung für Stadtentwicklung. Dort gehen mehrere Mitarbeiter, die für Radverkehr verantwortlich waren in der Ruhestand und es es ist zu berfürchten, dass diese Stellen zunächst nicht neu besetzt werden können.

English translation:

The Berliner "Fahrrat as a tool to involve Associations works very well, since there are only participants who would like to promote cycling. Public participation however definitely should be improved.

At the moment BUND is worried about the cost cuts in the local authorities in the department of transportation. Several employees, in charge of cycling traffic are going to retire, and it is feared that these positions will not be filled again.

4.What causes the most difficulties in the process of developing cycling infrastructure? (Was verursacht die größten Schwierigkeiten während der Entwicklung der Fahrradinfrastruktur?)

Immer wieder wurden von der Senatsverwaltung Gelder aus den beiden Haushaltsposten für den Radverkehr für eine Maßnahme in einem Bezirk reserviert, die dann nicht vollendet werden konnte. Dadurch konnte der Radverkehretat fast nie ausgeschöpft werden, obwohl es eine lange Warteliste von weiteren dringenden Maßnahmen gibt. Dies liegt daran, dass in den Tiefbauämtern der Bezirke so viel gespart wurde, dass es kaum noch Personal für die Umsetzung dieser Maßnahmen gibt. In Zukunft erfordert es daher für eine erfolgreiche Radverkehrsförderung eine intensivere Koordination.

5.What do you think is the most important factor to get people to cycle? (Was halten Sie für den wichtigsten Aspekt um Menschen zum Fahrradfahren zu bringen?

Die Entwicklung der Infrastruktur muss bei der Förderung des Radverkehrs die unterschiedlichen Zielgruppen berücksichtigen. Schnelle Radfahrer (auch pedelec-Nutzer) kommen gerne auch direkt und ohne Umwege ans Ziel. Für diese sind die Fahrradspuren auf den Hauptverkehrsstraßen am attraktivsten. Dort gibt es auch bereits eine Beschilderung, so dass die Orientierung leichter fällt.

Langsamere Radler bewegen sich lieber abseits der Hauptverkehrsstraßen, weil es dort sicherer und ruhiger ist und die Luftqualität besser ist. Hierfür sind Velorouten das beste Angebot, die zum Einen auf separaten (grünen)Wegen durch Grünanlagen und an Wasserläufer geführt werden, zum Anderen auf den aspahltierten Nebenstraßen. Die Velorouten sind separat beschildert. mehr dazu: http://www.stadtentwicklung.berlin.de/verkehr/mobil/fahrrad/radrouten/index.shtml

English translation:

The development of the cycling infrastructure has to consider during the promotion of cycling the different target groups. Faster riders prefer to get to their destination directly without any detours. For them, the cycle lanes along the main roads are the most attractive. On those roads there is also signage, in order to make orientation easier.

Slower cyclists prefer to cycle off the main roads, because it is safer, calmer and the air quality is better. For them, the Veloroutes are the best offer, which lead on the one hand side through separated green paths and waterfronts, on the other and through asphalted side streets. The veloroutes have a separate signage, more information on them: http://www.stadtentwicklung.berlin.de/verkehr/mobil/fahrrad/radrouten/index.shtml

6.What do you think are the reasons for Berlin not developing such a high modal share of cyclists as Copenhagen? (Was sind Ihrer Meinung nach die Gründe, das Berlin kein so hoher Anteil an Fahrradfahrer erreicht als Kopenhagen?)

1. Berlin ist flächenmäßig deutlich größer als Kopenhagen, weil man im 1920 fast 50 Dörfer und 7 Städte eingemeindet hat. So ist in den Innenstadtbezirken der radverkehrsanteil deutlich höher:

Friedrichshain-Kreuzberg: 21%
Pankow: 17%
Mitte: 14%
im Vergleich am Stadtrand:
Spandau: 8%
Marzahn-Hellersdorf: 6%
(Quelle: Verkehrsmittelwahl der Berliner Bevölkerung - Mobilität in Städten – SrV 2008)
2. Die auto-orientierte Verkehrspolitik im der Zeit zwischen 1955 und 1997 hat das Fahrrad an den Rand gedrängt.

English translation:

1.The surface of Berlin, in comparison to Copenhagen is much larger, because in 1920 around 50 villages and 7 towns were incorporated. The cycle share in the inner city districts is distinctly higher:

Friedrichshain-Kreuzberg: 21%
Pankow: 17%
Mitte: 14%
In Comparison the periphery:
Spandau: 8%
Marzahn-Hellersdorf: 6%
(Source: Verkehrsmittelwahl der Berliner Bevölkerung - Mobilität in Städten – SrV 2008)
2.The car oriented traffic policies in the years between 1955-1997 marginalized cycling.

7.Which are the main aspects that Berlin should import from Copenhagen, if any? (Welche sind die wichtigsten Aspekte (im Zusammenhang mit der Fahrradinfrastruktur) die Berlin von Copenhagen importieren soll, falls es welche gibt?)

- Die Berücksichtigung des Radverkehrs bei allen Plänen von der Stadtplnung bis zum Bebauungsplan
- Das Fahrradklima
- Grüne Welle für den Radverkehr

English translation:

-The consideration of cycling traffic in all plans ranging from urban plans to land use plans.

-The cycling atmosphere

-Green wave for cyclists

8.3 Accidents listing

The following list has been extracted from the report of the Berlin Police. All locations marked in grey were not included in the map, since they were located outside of the used map.

Area	Street name(s)	Nr. of accidents
Reinickendorf	Oranienburger Str.	13
	Oranienburger Str. / Taldorfer weg	1
	Oranienburger Str. / Techowpromenade	1
Pankow	Berliner Str.	10
	Berliner Str. / Binzstr.	1
	Berliner Str. / Breite Str.	3
	Berliner Str. / Brennerstr. /Mühlenstr. / Vinetastr.	2
	Berliner Str. / Elsa-Brändström-Str.	1
	Berliner Str. / Esplanade / Westerlandstr.	2
	Berliner Str. / Florastr.	2
	Berliner Str. / Granitzstr. / Kissingenstr.	2
	Berliner Str. / Hadlichstr.	4
	Berliner Str. / Maximilianstr.	2
	Berliner Str. / Mühlenstr. / Tiroler Str.	1
Weißensee	Berliner Allee	14
Prenzlauer Berg	Bornholmer Str. / Schönhauser Allee / Wisbyer Str.	11
	Bornholmer Str.	2
	Bornholmer Str. / Bergen Str.	1
	Bornholmer Str. / Björnsonstr. / Malmöer Str.	2
	Bornholmer Str. / Schönfließer Str. / Stavangerstr.	3
Prenzlauer Berg	Danziger Str. / Eberswalder Str. / Kastanienalle / Pappelallee	10
	Danziger Str.	7
	Danziger Str. / Dunckerstr. /	2
	Danziger Str. / Knaackstr. / Lychener Str.	2
	Danziger Str. / Kollwitzstr. / Senefelderstr.	2
Prenzlauer Berg	Kastanienallee	11
Prenzlauer Berg	Schönhauser Allee	28
	Schönhauser Allee / Wicherstr. / Schivelbeiner Str.	8
	Schönhauser Allee / Wörther Str.	2
Prenzlauer Berg	Danziger Str. / Greifswalder Str.	10
	Danziger Str.	7
	Danziger Str. / Bützowstr. / Arnswalder Platz	1
	Danziger Str. / Cotheniusstr.	1
	Danziger Str. / Ella-Kay-Str.	3
	Danziger Str. / Paul-Heyse-Str.	1
	Danziger Str. / Prenzlauer Allee	8
	Danziger Str. / Rudi-Arndt-Str. / Freizeitpark am S.	1
	Danziger Str. / Rykestr.	2
	Danziger Str. / Winsstr.	2

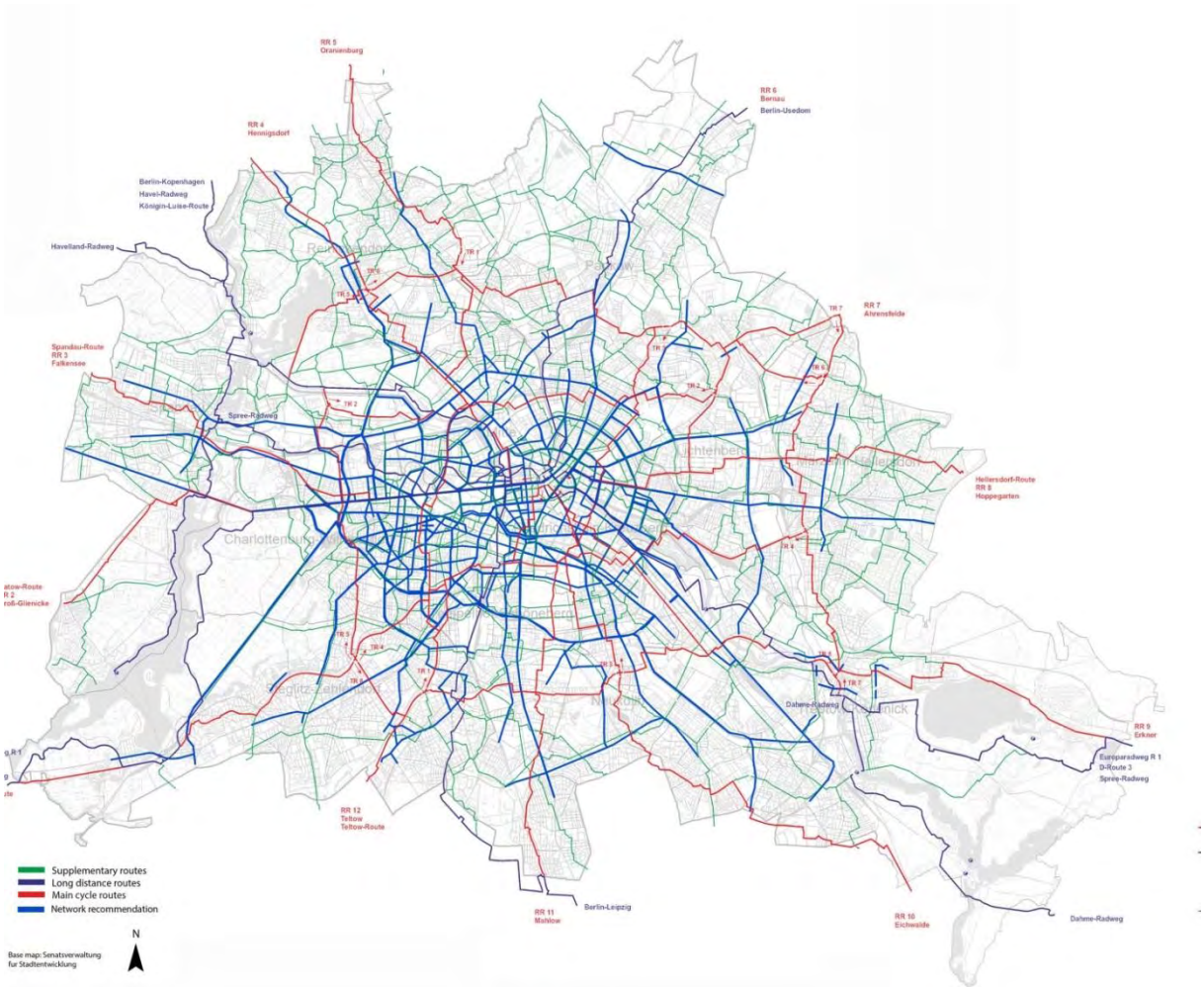
Prenzlauer Berg	Greifswalder Str.	19
	Greifswalder Str. / Bernhard-Lichtenberg-Str. / Ernst-Thälman-P.	1
	Greifswalder Str. / Grellstr. Storkower Str.	3
	Greifswalder Str. / Heinrich-Roller-Str	1
	Greifswalder Str. / Hufelandstr. / Marienburger Str.	1
	Greifswalder Str. / Immanuelkirchstr.	2
	Greifswalder Str. / Lilli-Henoch-Str.	1
	Greifswalder Str. / Michelangelostr. / Ostseestr.	5
	Greifswalder Str. / Schieritzstr.	2
Prenzlauer Berg	Storkower Str.	10
Prenzlauer Berg	Storkower Str. / Landsberger Allee	10
Spandau	Nonnendammallee	10
	Nonnendammallee / Boltonstr.	1
	Nonnendammallee / Otternbuchstr.	3
	Nonnendammallee / Rohrdamm	2
Charlottenburg	Heerstr.	12
	Heerstr. / Jaffestr. / Länderallee	1
	Heerstr. / Kranzallee / Flatowallee	1
	Heerstr. / Mohrunger Allee / Ortelsburger Allee	1
	Heerstr. / Soldauer Allee / Teufelsseestr.	1
	Heerstr. / Theodor-Heuss-Platz	1
Spandau	Brunsbötteler Damm	11
	Brunsbötteler Damm / Am Bahnhof Spandau	4
	Brunsbötteler Damm / Egelpfuhlstr.	1
	Brunsbötteler Damm / Elsflether Weg	1
	Brunsbötteler Damm / Harburger Weg	1
	Brunsbötteler Damm / Klosterstr. / Ruhlebener Str.	6
	Brunsbötteler Damm / Magistratsweg	1
	Brunsbötteler Damm / Nauener Str.	2
	Brunsbötteler Damm / Päwesiner Weg	2
	Brunsbötteler Damm / Prisdorfer Str.	1
Charlottenburg	Kurfürstendamm	15
	Kurfürstendamm / Meinekestr.	2
	Kurfürstendamm / Rankestr. / Tautzienstr. / Breitscheidplatz	1
	Kurfürstendamm / Schlüterstr.	2
	Kurfürstendamm / Wielandstr.	1
Wilmersdorf	Bundesallee / Hohenzollerndamm / Nachodstr.	11
	Bundesallee / Trautenaustr.	4
	Bundesallee	9
	Bundesallee / Detmolder Str. / Wexstr. / Bundesplatz	7
	Bundesallee / Durlacher Str. / Hildegardstr.	1
	Bundesallee / Güntzelstr.	2
Mitte	Brunnenstr.	15
	Brunnenstr. / Invalidenstr.	4
	Brunnenstr. / Torstr. / Rosenthaler Platz	6
Mitte	Chauseestr.	11

	Chauseestr. / Friedrichstr. / Torstr.	3
	Chauseestr. / Invalidenstr.	3
	Chauseestr. / Tieckstr.	1
	Chauseestr. / Zinnowitzer Str.	2
Mitte	Torstr.	15
	Torstr. / Alte Schönhauser Str. / Rosa-Luxemburg-Str.	10
	Torstr. / Straßburger Str. / Zolastr.	1
	Torstr. / Tucholskystr.	1
Mitte	Friedrichstr.	16
	Friedrichstr. / Französichier Str.	5
	Friedrichstr. / Georgenstr.	1
	Friedrichstr. / Jägerstr.	1
	Friedrichstr. / Krausenstr.	3
	Friedrichstr. / Leipziger Str.	3
	Friedrichstr. / Mohrenstr.	4
	Friedrichstr. / Reichstagsufer / Am Weidendamm / Weidendammer Brücke	2
	Friedrichstr. / Schützenstr.	2
	Friedrichstr. / Unter den Linden	8
	Friedrichstr. / Zimmerstr.	1
Mitte	Karl-Liebknecht-Str.	11
Mitte	Otto-Braun-Str / Alexanderstr. / Karl-Marx-Allee	16
Mitte	Otto-Braun-Str. / Mollstr.	17
	Otto-Braun-Str	1
Mitte	Unter den Linden	10
Wedding	Müllerstr.	24
	Müllerstr. / Nazarethkirchstr.	3
	Müllerstr. / Otawistr. / Schöningstr.	1
	Müllerstr. / Seestr.	5
Schöneberg	Hauptstr.	20
	Hauptstr. / Helmstr.	1
	Hauptstr. / Kaiser_wilhelm-Platz	1
	Hauptstr. / Körntener Str.	2
	Hauptstr. / Koburger Str.	1
	Hauptstr. / Martin-Luther-Str.	1
	Hauptstr. / Rheinstr.	1
	Hauptstr. / Rubensstr.	1
	Hauptstr. / Wexstr. / A100 BAB / Innsbrucker Platz	5
Zehlendorf	Königstr.	14
	Königstr. / Kronprinzessinnenweg	5
	Königstr. / Martin-Buber-Str.	1
	Königstr. / Martin-Buber-Str. / Onkel-Tom-Str.	2
Tempelhof	Tempelhofer Damm	14
	Tempelhofer Damm / Wolfring	1
Tempelhof	Lichtenrader Damm	12
	Lichtenrader Damm / Löptener Str.	1
	Lichtenrader Damm / Marienfelder Str.	1

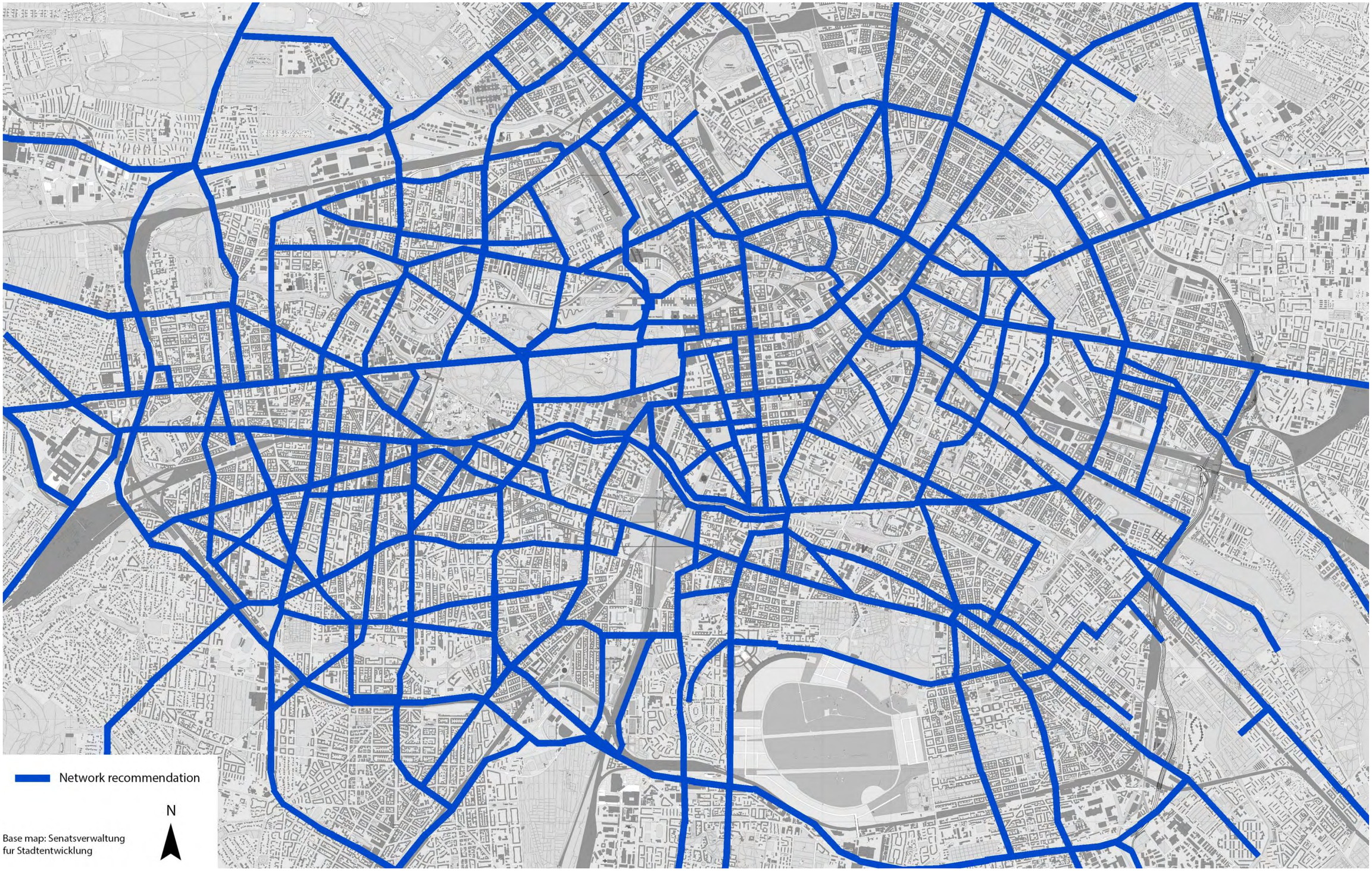
Friedrichshain	Frankfurter Allee	10
	Frankfurter Allee / Gabelsbergerstr.	2
	Frankfurter Allee / Jungstr. / Voigtstr.	2
	Frankfurter Allee / Kinzigstr.	1
	Frankfurter Allee / Niederbarnimstr.	9
	Frankfurter Allee / Samariterstr.	1
	Frankfurter Allee / Waldeyerstr. / Weichelstr.	1
Friedrichshain	Frankfurter Tor	13
Friedrichshain	Karl-Marx-Allee	13
	Karl-Marx-Allee / Koppenstr.	5
	Karl-Marx-Allee / Strusberger Platz	1
Friedrichshain	Mühlenstr. / Stralauer Allee / Warschauer Str. / Am Oberbaum	15
	Mühlenstr.	3
Friedrichshain	Straße der Pariser Kommune / Karl-Marx-Allee	11
	Straße der Pariser Kommune	1
	Straße der Pariser Kommune / Franz-Mehring-Platz	2
	Straße der Pariser Kommune / Mühlenstr. / Stralauer Platz	3
Friedrichshain	Warschauer Str.	24
Kreuzberg	Blücherstr. / Zossener Str.	12
	Blücherstr.	3
	Blücherstr. / Blücher Platz	1
	Blücherstr. / Brachvogelstr. / Mittenwalder Str.	6
	Blücherstr. / Mehringdamm / Obentrautstr.	5
	Blücherstr. / Südstern	1
Kreuzberg	Gneisenaustr.	11
	Gneisenaustr. / Mehringdamm / Yorckstr.	9
	Gneisenaustr. / Mittenwalder Str.	3
	Gneisenaustr. / Nostiztstr.	4
	Gneisenaustr. / Schleiermacherstr.	2
	Gneisenaustr. / Südstern	1
	Gneisenaustr. / Zossener Str. / Ubhf. Gneisenaustr.	1
Kreuzberg	Hasenheide	17
	Hasenheide / Jahnstr.	2
	Hasenheide / Lilienthalstr. / Südstern	4
	Hasenheide / Wissmannstr.	1
Kreuzberg	Kottbusser Damm	13
	Kottbusser Damm / Machbachufer / Planufer / Kottbusser Brücke	4
	Kottbusser Damm / Sanderstr.	1
	Kottbusser Damm / Wesestr.	3
Kreuzberg	Kottbusser Damm / Urbanstr. / Hermannplatz / Sonnenalle	11
Kreuzberg	Admiralstr. / Kottbusser str. / Reichenberger Str. / Skalitzer Str.	16
Kreuzberg	Oranienstr.	28
	Oranienstr. / Adalbertstr.	7
	Oranienstr. / Alexandrinenstr.	1
	Oranienstr. / Alte Jakobstr.	1
	Oranienstr. / Axel-Springer-Str. / Rudi-Dutschke-Str.	2

	Oranienstr. / Moritzplatz	11
	Oranienstr. / Oranienplatz	3
	Oranienstr. / Prinzessinnenstr.	2
	Oranienstr. / Stallschreiberstr.	1
Kreuzberg	Prinzenstr. / Moritzplatz	17
	Prinzenstr.	9
	Prinzenstr. / Ritterstr.	1
	Prinzenstr. / Wassertorstr.	4
Kreuzberg	Skalitzer Str.	12
	Skalitzer Str. / Spreewaldplatz	1
Neukölln	Sonnenallee	18
Neukölln	Weserstr.	11
	Weserstr. / Treptower Str.	1
	Weserstr. Wildenbruchstr.	1
Neukölln	Hasenheide / Hermannstr. / Karl-Marx-Str.	10
Neukölln	Hermannstr.	20
	Hermannstr. / Herrfurthstr.	4
	Hermannstr. / Jonasstr.	3
	Hermannstr. / Kienitzer Str.	1
	Hermannstr. / Leinestr.	1
	Hermannstr. / Schierker Str.	1
	Hermannstr. / Thomasstr.	1
Neukölln	Karl-Marx-Str.	28
	Karl-Marx-Str. / Lahnstr. / Silbersteinstr.	4
	Karl-Marx-Str. / Reuterstr.	4
	Karl-Marx-Str. / Saltykowstr.	1
	Karl-Marx-Str. / Schönstedstr.	1
	Karl-Marx-Str. / Thomasstr. / Karl-Marx-Platz	1
	Karl-Marx-Str. / Uthmannstr.	1
	Karl-Marx-Str. / Weichselstr.	2
Treptow	Puschkinalle	10
	Puschkinallee / Eichenstr.	2
	Schnellerstr.	12
Köpenick	Wendensschloßstr.	12
Köpenick	Wilhelminenhofstr.	13
	Extra example	
Mitte	Alexanderstr.	7
	Alexanderstr. / Grunerstr.	6
	Alexanderstr. / Holzmarktstr. / Stralauer Str.	8
	Alexanderstr. / Karl-Liebknechtstr. / Memhardstr.	9
	Alexanderstr. / Magazinstr. / Voltairestr.	1
	Alexanderstr. / Schicklerstr.	3
	Alexanderstr. / Schillingstr.	1

8.4 Comparison of planned network and recommended network



8.5 Network recommendation inner city



8.6 Network recommendation city scale