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Keywords:

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Abstract:

Increased bicycling is of great importance for a sustainable transport system. This report is the result of a literature study concerning how different factors associated with bicycle planning influence the propensity to choose the bicycle for transportation. The literature study was carried out in the search engine GoogleScholar and only scientific papers, articles and books were included. Through this literature review, knowledge has been gathered concerning bicycle planning, policies and other factors that influence the use of the bicycle in daily transport. . Through the literature study it became evident that the attractiveness of the bicycle should be seen in relation to the car. If it is more attractive to use motorised modes of transport (e.g. through parking norms, costs, level of service) it will be hard to convince people to use the bike instead of the car. It also became clear that there are big differences in how research concerning bicycling and bicycle planning is conducted and there is e.g. no research based on before- and after studies. Despite this, the results are often very consistent. For instance, the results show that the bicycle infrastructure is of great importance. This implies that if appropriate infrastructure is build people tend to use the bicycle more often. In terms of policy, the time factor seems to be an important issue. This in turn implies, with policies and strategies being consistent over longer time intervals, the impact on the use of the bicycle increases.

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Content

Preface

This report was written within the Vinnova financed project “Planning of strategic bicycle infrastructure”. It is a literature review of recent scientific literature on bicycle planning and is the first publication within this project. The project is a collaboration between Transport and Roads, Lund University, Urban Studies, Malmö University and Mobility, actors and planning processes VTI. Lund University leads the project in close cooperation with the reference group, which consist of Janet van der Meulen, Swedish Transport Administration, Ulf Bredby, City of Mölndal, Jesper Nordlund and Sara Forslund, City of Malmö and Lars Strömgren, Cykelfrämjandet.

Till Koglin is the project manager of the project and has written this report together with Hampus Ekblad and Åse Svensson. They all work at Transport and Roads, Lund University.

Lund, December 2016

Summary

Increased bicycling is of great importance for a sustainable transport system. In order to increase the modal share of bicycling, transport and bicycle planning has to tackle several issues. Often it is not quite clear what is needed in terms of planning for increasing bicycling. This report is the result of a literature study concerning how different factors associated with bicycle planning influence the propensity to choose the bicycle for transportation. The literature study was carried out in the search engine GoogleScholar and only scientific papers, articles and books were included. Through this literature review, knowledge has been gathered concerning bicycle planning, policies and other factors that influence the use of the bicycle in daily transport. The ambition was to gather most state-of-the-art research publications concerning these issues. Through the literature study it became evident that the attractiveness of the bicycle should be seen in relation to the car. If it is more attractive to use motorised modes of transport (e.g. through parking norms, costs, level of service) it will be hard to convince people to use the bike instead of the car. It also became clear that there are big differences in how research concerning bicycling and bicycle planning is conducted and there is e.g. no research based on before- and after studies. Despite this, the results are often very consistent. For instance, the results show that the bicycle infrastructure is of great importance. This implies that if appropriate infrastructure is build people tend to use the bicycle more often. In terms of policy, the time factor seems to be an important issue. This in turn implies, with policies and strategies being consistent over longer time intervals, the impact on the use of the bicycle increases.

Sammanfattning

Ökad cykling har stor betydelse för ett hållbart transportsystem. För att öka andelen resor med cykel måste dock trafik- och cykelplaneringen ta itu med ett flertal olika problem. Det är emellertid inte alltid fullständigt klart vad som behövs gällande planering för att öka cyklingen. Denna rapport är resultatet av en litteraturstudie om hur olika faktor kopplade till cykelplanering påverkar benägenheten att välja cykeln för transport. Litteraturstudien genomfördes i sökmotorn GoogleScholar och endast vetenskapliga rapporter, artiklar och böcker har ingått. Genom denna litteraturstudie har kunskap samlats om cykelplanering, policyer och andra faktorer som påverkar användningen av cykeln för dagliga transporter. Ambitionen var att samla in de flesta state-of-the-art forskningspublikationer som berör dessa frågor. Genom litteraturstudien blev det uppenbart att cykelns attraktionskraft bör ses i förhållande till bilen. Om motoriserade transportsätt är mer attraktiva att använda (t.ex. genom parkeringsnormer, kostnader, framkomlighet) kommer det också att vara svårt att övertyga människor att använda cykeln i stället för bilen. Det blev också tydligt att det finns stora skillnader i hur forskning kring cykling och cykelplanering bedrivs och att det saknas forskning baserat på före- och efterstudier. Men resultaten är trots detta ofta mycket samstämmiga. Resultaten visar bland annat att cykelinfrastrukturen har stor betydelse. Detta innebär att om rätt infrastruktur byggs tenderar människor att använda cykeln oftare. När det gäller policyer för cykling tycks tidsfaktorn vara viktig. Detta innebär att med policyer och strategier som är konsistenta över längre tidsperioder ökar också deras inverkan på användningen av cykeln.

1 Introduction

Road transport today contributes to several problems, such as air and noise pollution, safety issues and social problem, such as the marginalisation of certain road users from public space (Gärling & Steg 2007; Englund et al 1998; Khayesi et al 2010). Bicycling, however, is a sustainable form of transport that does not pollute, poses very little risks to other road users, is a healthy mode of transport and takes up very little space, compared for example to the car (Koglin 2013; Garrard et al. 2012; Tranter 2012; Cooper et al. 2008). Moreover, bicycling has been on the agenda of many cities, especially in Europe and many cities are trying to improve the condition for bicyclists in order to increase the modal share of bicycling (Koglin 2013; Aldred 2013; Koglin 2015a; Koglin 2015b; Lanzendorf & Busch-Geertsema 2014; Pucher & Buehler 2012; Pucher, & Buehler 2009).

Nevertheless, within transport planning, bicycling is quite marginalised and many solutions that are implemented for bicycle traffic are not always the best when considering e.g. accessibility, comfort or safety (Koglin 2013; Koglin & Rye 2014; Furness 2010; Emanuel 2012). Furthermore, the modal share of bicycling in many cities does not increase as much as it was hoped for. Therefore, it is important to take a closer look at the scientific literature on bicycle planning in order to collect the knowledge that does already exist on bicycle planning and what kind of measures do seem to work well for bicycling and what factors really can lead to an increase of bicycling in the modal share of cities.

Previous research about bicycle planning has often dealt with so called best practise studies that focused on cities like Copenhagen or Amsterdam with high rates of cycling, but do not consider the overall transport planning, and transport systems in the cities (Sick Nielsen et al. 2013; Pucher & Buehler 2007; 2008). However, quite often these studies lack of scientific evident based knowledge about why certain infrastructural measures seem to work better than others and if the high rate of cycling in these cities depend on infrastructural measures or on other aspects, such as socio-economic or cultural ones. With this literature study it is our goal to provide a knowledge base also on factors that are not shown in such best practise studies in order to improve the knowledge base of what actually affects the modal share when it comes to bicycling.

1.1 Aim and research questions

The aim of this literature review is to get an overview of the state of the art in research that is concerned with bicycle planning in an urban context in order to develop more knowledge of the gaps that needs to be filled with new research. Furthermore, this literature study aims at collecting success factors that research has shown work in cities in different context and might be implemented in other urban contexts. Without preceding the literature study we do already now anticipate difficulties finding proper before- and after-studies based on specified indicators

revealing the impact on cycling due to different measures introduced. Therefore in order to live up to the aim of this literature study the research questions must be more generic.

The overarching research question is:

What seems to be important for increasing bicycling in cities?

The more specific research questions are then formulated as:

- What can be found in the literature regarding what characterises are more successful and less successful strategies in different studies/cities in relation to:
    - Policies
    - Planning
    - Factors, measures and infrastructure
    - Urban form and land use

and finally – What implementation challenges are at stake?

1.2 Method

The field of bicycling and bicycle planning today is quite large and broad and there is a wide range of research that has dealt with these matters, which has led to a large number of scientific reports, articles and books. It is therefore rather impossible to cover all research publications in this field. Therefore limitations, selections and exclusions have been made by the authors. This literature study focuses only on urban contexts and through selections of keywords limitations have been made. This literature study also only includes scientific publications and excludes consultants' reports or studies made by municipalities and cities.

The method for answering the research questions was conducting a systematic literature search and review. The following search terms and combinations have been used in order to collect the most recent literature about bicycle planning:

cycl* OR bicycl* AND planning AND urban OR city OR cities

cycl* OR bicycl* AND planning AND urban OR city OR cities AND polic*

cycl* OR bicycl* AND factor* OR indicator* OR variable*

cycl* OR bicycl* AND "modal choice" AND factor* OR indicator* OR variable*

cycl* OR bicycl* AND impact* OR effect* OR affect*

cycl* OR bicycl* AND flow*

cycl* OR bicycl* AND demand

cycl* OR bicycl* AND behavio*r*

cycl* OR bicycl* AND implementation AND planning

cycl* OR bicycl* AND “urban form” OR “land use”

cycl* OR bicycl* AND group*

cycl* OR bicycl* AND urban OR city OR cities AND mobility OR mobilities

velomobility OR vélomobility AND planning AND urban OR city OR cities

cycl* OR bicycl* AND policy OR policies

cycl* OR bicycl* AND transport* OR traffic OR travel

cycl* OR bicycl* AND infrastructure AND urban OR city OR cities

The time interval was 2010-2016 in order to only include the latest and state of the art research in this review. Moreover, the literature search has been carried out through the search engine GoogleScholar and the Lund University database LubSearch. Besides the literature found through the literature search, scientific literature that might not have been included in the search results, but was known to the authors of this report have been included in this study. Overall over 100 scientific articles and books have been read through in order to develop an understanding of the latest research on bicycle planning, infrastructure etc.

2 Bicycle planning, policies and land use

Several researchers have written about bicycle planning and policies in recent years (e.g. Koglin 2013; 2015a; b Koglin & Rye 2014; Buehler & Pucher 2011; Sick Nielsen et al. 2013). This chapter deals with the question of what can be found in the literature regarding what characterises more successful and less successful strategies in different studies/cities in relation to planning, policies and land use/urban form. Hopefully the analysis in this chapter will give input in what success factors can be found regarding planning, policies and urban form, and if implemented may lead to an increase in cycling in the modal split of cities.

Koglin (2013; 2015a) compared transport planning policies in Copenhagen, Denmark, and Stockholm, Sweden. He could show that these are influenced by different power relations and that this has an effect on how bicycling is prioritised within the transport planning field in Copenhagen and Stockholm. His case studies have shown that historical, cultural, economic and political aspects play an important role in whether transport planners focus on planning for bicycling or not. These aspects are e.g. the overall culture in the cities in favour of bicycling or motorised transport, the historical development of the transport planning field or the political decision making. In his research Koglin (2013; 2015a) shows that the political attitude in Copenhagen has been in favour of the bicycle since the 1970s, which was not the case in Stockholm. This has formed the basis of planning for cycling in Copenhagen, Moreover, due to lack of funding opportunities after the WWII Copenhagen focused on rather cheap solution concerning transport, in this case cycling. This has influenced transport planning in both cities and has led to the development of much better infrastructure for cycling in Copenhagen compared to Stockholm.

In another article by Koglin (2015b) he compares the organisation of transport and urban planning in Stockholm and Copenhagen. Through his research he concludes that urban and transport planning are much more integrated in Copenhagen than in Stockholm and the bicycling plays a much larger role with transport and urban planning in Copenhagen than in Stockholm. This has thus led to the fact that cycling is much more integrated in all steps in transport and urban planning and through that are less marginalised in Copenhagen compared to Stockholm. All the research mentioned here by Koglin is based on interview studies with planners and politicians on both Stockholm and Copenhagen.

Buehler et al. (2009) compared transport policies concerning sustainability between Germany and the United States of America. They conclude with five lessons from Germany:

- Get the price right – Make the motorists pay “the real price” of their choice.
- Integrate transit, cycling and walking as viable alternatives to the car – here they mostly discuss soft measures but also discuss system building.

- Fully coordinate and integrate planning for land use and transportation – land use and transport planning need to be integrated because certain land use patterns make it easier or harder to use the bicycle.
- Public information and education to make changes feasible.
- Implement policies in stages with a long term perspective – here it is argued that it took considerable time for Germany to get where they are and that it takes time to get changes in the transportation system

These steps are seen by Buehler et al. (2009) as very important to achieve good bicycling conditions.

In another article Buehler and Pucher (2011) discuss and compare policies in Germany and USA, but primarily from Freiburg in Germany. Freiburg had an early focus on cycling, walking and public transport following the bombings of the city centre during WWII. This focus consisted e.g. of early bicycle plans and large pedestrian zones. Furthermore, certain events are mentioned that influenced the shift from car focused planning in the 1960s to a less car focused planning in the 1970s. These events were for example abandoning a second car focused city plan, the planning of a nuclear power plant nearby and the oil crisis in 1973. Such events had a major impact on the policies of the city of Freiburg and led to a focus on sustainable urban transport planning (Buehler & Pucher 2011).

Cui et al. (2014) developed a bicycle ridership model for the State of Maryland, USA. Factors like demographic, socio-economic, land use and attributes of the transport system were correlated against bicycle trips to investigate how the factors affect the number of cycling trip. The study shows factors that affect the proportion of bicycle trips positively are population density, household density, and school enrollment density. Also, variables like number of retail stores and recreational locations have a positive effect on bicycle share. Furthermore, the study shows that transit (bus and train) accessibility effects bicycle trips positively, which indicates that bike-and-ride is one way to encourage cycling (Cui et al. 2014).

A study of 20 German municipalities made by Goetzke and Rave (2011) uses a bicycle choice model and municipal-level social network effects variable as an indication of cycle culture. Interpreting social network effects as a signal that bicycling is safe and reliable, the study's main claim is that the utility of taking a bicycle increases with its mode share. Therefore, the more people use a bicycle, the more attractive a bicycle ride becomes to other people. These social spillover effects lead to positive demand-side network externalities, which in this study also is referred to as bicycling culture. They also show that social network effects may not have a very large impact on work/school trips but larger on other trips like shopping, errands and recreation (Goetzke & Rave 2011).

Gössling (2013) made a qualitative overview of Copenhagen's cycling history with focus on measures and how these are communicated. The research found three arguments for cycling that Copenhagen uses to for its cycle planning: a more desirable urban future, individual and societal benefits, and opportunities for participation. Gössling also argues that a big part of Copenhagen's success comes from the city's self-proclaimed bike friendliness. Other interesting findings are that even though 33% of cyclists say that rain is their main reason for not cycling, information from the Danish Meteorological Institute [DMI] show that an

equivalent of 3.5% of the trips cycled by an average cyclist was in fact done in rain (Gössling 2013).

Harms et al. (2014) used descriptive bivariate statistics to explore social and spatial differences in cycling patterns. The researchers categorised built environment into 5 classes of urbanisation and used the National Travel Survey for the Netherlands to analyse where people cycle the most, in the Netherlands. The results show that highly urbanised (1500-2500 addresses per square kilometre) areas generate more cycling trips and less urbanised (500-1000 addresses per square kilometre), less cycling trips. But they also show that this relationship is not linear and moderate urbanisation (1000-1500 addresses per square kilometre) generates as much cycling trips as highly urbanised areas (Harms et al. 2014).

Harms et al. (2015) also examined factors for effectiveness for 22 mid-sized Dutch cities, using rough set analysis. Data came from policy makers and volunteers form the Dutch cycling union who were questioned, with 50 questions, about hardware, software, orgware, conditions, performance measures, and changes in these conditions and measures. Data also came from the national data survey, one mobility survey and social-, demographic- and spatial data. The results show that improving cycling infrastructure, the organisation implementation of cycling policies, education and information are good ways to improve cycling. But they also show that external factors impact the effectiveness of the policies. Improving quantity and quality of cycling infrastructure while at the same time decreasing attractiveness of car use seem to be critical success factors for increasing cycling share (Harms et al. 2015).

Lanzendorf et al. (2014) evaluated policies and amounts of cycling in four German cities. Two data sources was used: document analysis and expert interviews, and a quantitative analysis of the German national travel survey. Using German national travel survey to compare the cities to the nation and to each other the researchers could see that one of the cities started promoting cycling later than the other three and its cycling share did not increase as much as the others (Lanzendorf et al. 2014).

Marsden et al. (2011) studied the transport policies of eleven larger cities in North America and Northern Europe. They tried to find what motivated cities to change their transport policies and what barriers could inhibit learning from other cities. This was done by studying policies and interviews with city representatives working with policies. The findings support that cities try to learn from other cities, but also that this learning is often a spontaneous, bottom-up action driven by the staff (Marsden et al. 2011).

A study by Mendolia et al. (2014) linked urban development and land use to modal split in Biscay, Spain. Using nationwide journey-to-work data was cross referenced to spatial data such as population concentration, gross income per capita, population growth, access to rail transport and more. They found that the factors with the greatest impact on modal split was population density, population concentration and, to lesser extent, the mix of functions in the area (Mendolia et al. 2014).

Owen et al. (2010) tried to find a connection between a city's walkability attributes and the amounts of bicycling in said city. Studies were made in Adelaide, Australia and Ghent, Belgium. The data collected consisted of sociodemographic attributes, bicycle use and environmental attributes. Results showed that participants living in an area with high

walkability had a higher chance of bicycling than in an area with lower walkability (Owen et al. 2010).

Pucher et al. (2007) compared six cities with relatively high amounts of cycling. The cities studied were Amsterdam, Groningen, Copenhagen, Odense, Berlin and Muenster in Netherlands, Denmark and Germany. The six cities are similar in size and cycling promotion effort with the exception of Berlin. The authors consider Berlin especially interesting since it is a bigger city which still put a lot of effort into promoting and planning for cycling. This is attributed to the fact that Berlin is a relatively poor city and therefor has to focus on cheaper traffic alternatives i.e. cycling (Pucher et al. 2007).

Pucher et al. (2009) examine differences in German and American cities. They see that there are big differences in the traffic system, emissions are lower, car efficiency is higher, transport costs less, there are less traffic fatalities and the government pay less for public transport in Germany than in the USA. These differences are attributed to five categories of policies that Germany has implemented. The five are *pricing and restrictions on car use, public transport improvements*, *walking and cycling in Germany* (improvements for these transport modes), *urban development and land use policies* and *coordinating policies*. The article puts weight on the correlation between lowering car use and increasing bicycle use and that this is one of the biggest difference between Germany and the USA (Pucher et al. 2009a).

In in a study of New York Pucher et al. (2010) examines how the city has improved its cycling focus. The study covers what has been, and not been, done in ways of cycle paths, bike parking, promotion, integration with public transport and more. The authors find that a lot has been done but more can be done, only 0.6 % of work trips was done by bike in 2008. Comprehensive cycle trend surveys are not preformed which makes it hard for planners to see what is missing and how the system can be improved. Heavy motorised traffic creates unsafe and unpleasant cycling and the authors recommend traffic calming measures to improve the quality of cycling in New York (Pucher et al. 2010a).

In another study, Pucher et al. (2011), examine bicycle share change in three cities in Canada and six in the USA. All the examined cities have had a significant growth in cycling trips over the last two decades. The study shows how the cities with the greatest focus on planning and building for cycling also are the ones with the largest share of bicycle trips. Although the amount of trips cannot be compared to European cities it still shows how focused efforts gain results. The study also finds that climate does not seem to have too big an effect on mode share; cities like Vancouver and Portland, Minneapolis and Montréal are successful regardless of their rainy and cold weather, respectively (Pucher et al. 2011).

Pucher et al. (2011) study bicycling in Australia, specifically in Melbourne and Sidney. The two cities have quite different bike tripe share. Despite of being very similar, Sidney has about half as much trips made by bike as Melbourne. Although much information is missing the authors attribute the greater amounts in Melbourne to flatter typography, milder climate, less traffic and greater connectivity of roads. They also see more favourable policies towards cycling in Melbourne than in Sidney, though there is lack of data in this field as well. Lacking from the Australian cities are measures to decrease car use, gas prices and general car fees are lower than in Europe (Pucher et al. 2011).

Rietveld et al. (2004) tried to explain which policy measures effect amounts of bicycle share and to what extent. The studied country was the Netherlands where cycling is common, but differences between municipalities still exist. Contributing factors were identified and a multiple regression analysis was carried out. The study was done for trips shorter than 7.5 km and the results showed that the most significant policy variables were the ones that improved the bicycles competiveness in relation to the car. Other significant variables were the ones that increased the safety and satisfaction for the cyclists (Rietveld et al. 2004).

Schoner et al. (2015) made a literature study and a model of mode share (on trips to work) to investigate the impact of built environment on transport mode choice. Mode share was based on a postal survey to residents in Minneapolis. The built environment characteristics was gathered by GIS-measurements and by asking questions in the postal survey. Results are in line with earlier findings but a few things stand out (Schoner et al. 2015).

In a study by Silva et al. (2014) potential travel behaviour and actual travel behaviour was compared in Copenhagen, Denmark and Oporto, Portugal using the structural accessibility layer (SAL), a spatial data tool created by the authors. It uses spatial data to create a potential travel behaviour, a theoretical value that is used to compare the two cities Copenhagen and Oporto. Note that cycling was not taken in consideration for Oporto since the authors did not deem this mode as significant in size. The comparison between the potential and actual travel behaviour seemed to suggest that the built environment has an impact on travel behaviour. Though the car did not seem to be as affected by the built environment as the other modes. Furthermore, the authors found that an important factor on mode choice was the diversity of activities in the area the user lives in. High diversity leads to more travels with non-motorised vehicles (Silva et al. 2014).

Stewart et al. (2014) made a GIS analysis of land use data and travel behaviour data in Puget Sound, Washington. The land use data consisted of ten different variables in the group's density, diversity, design, affordable housing and a weighted composite index consisting of the other variables (not housing). The travel data consisted of a survey with 3937 answers. The information used in this data was binary coding of whether the household had done at least one walk, transit or bike trip during the two-day survey period. These data were then analysed to examine how the different variables in the land use data impacted the travel mode choice and with the intention to see how effective built-environment data is for oversampling households with rare travel behaviors. The results show that block size seems the best variable to use for oversampling in this case (Stewart et al. 2014).

Winters et al. (2010) investigated factors related to cycling trips. Instead of using the "classic" methodology of creating a set distance from home and investigate the land use in this distance, something that might be useful for examining walking trips, the authors tried to find a methodology more suitable for cycling. They found that the top four motivators for making a trip by bicycle were related to routes: being away from traffic and noise pollution, having beautiful scenery, having separated bicycle paths for the entire distance, and having flat topography. Data came from the local travel data survey for Metro Vancouver, after excluding participants that stated that they did not and would not cycle in the future. The data set consisted of 3280 trips made by 1902 participants (Winters et al. 2010).

3 Attitude and (bicycle) culture

Based on a huge literature review Heinen et al. (2009) conclude that attitude appears to be a factor of particular explanatory power when analysing reasons for commuting by bicycle. When analysing predictors of the intention to use different travel modes, attitude and perceived behavioural control were significant predictors, while subjective norm was only a significant predictor of intention to use the car (Eriksson & Forward 2011). Individual attitudes as "I like biking" were significant in explaining bicycle commuting in Handy & Xing (2011). Handy and Xing (2011) also found that perceived attitudes among supervisors at the workplace was associated with bicycle commuting, while perceptions and attitudes of co-workers were not associated with bicycle commuting. Also Heinen et al. (2013) find that perceived social norms seem to be of importance for bicycle commuting. But contrary to Handy and Xing (2011) the authors found that if colleagues are bicycle commuters the individual will be positively influenced to also be a bicycle commuter. Based on a literature study on factors affecting cycling and where factors are "weighted" depending on number of studies and significant results Lindelöw (2009) does not find any evidence of attitudes being of importance.

Several studies refer to bicycle culture being of importance, but what is bicycle culture?. Sick Nielsen et al. (2013) found that beyond specific factors (described later) the probability to cycle and cycling distance correlate with the city dummies. When Carse et al. (2013) studied factors influencing car use in a cycle-friendly city as Cambridge they refer to "Cambridge's cycling citizenship" when explaining that the cycling culture is so strong that even individuals in car-owning households cycle. The same but different was raised by Daley & Rissel (2011) when in focus groups discussing the low levels of cycling in Sydney. They considered cycling's low status in Sydney was due to the city's prevailing *car culture*. According to Wardman et al. (2007) commuters are more likely to cycle where cycling levels are high – all other things equal. They argue that these cultural factors may explain the extraordinarily high levels of cycling in some areas in Northern Europe. They also found that the "proportion of the general population cycling" has a greater impact than "proportion of colleagues cycling" and estimate a 10% increase in the general population cycling has the same effect as 1.0 minute bicycle time reduction. Coming back to Daley & Rissel (2011) it is worth mentioning the quite different perceptions of cycling in Sydney as compared to perceptions where cycling is more common. While there was greater acceptance of recreational riding and cycling for sport and exercise, riding for transport or bicycle couriers were not viewed as a mainstream activity. The low acceptance of the two latter was explained by these being *rule breakers* and *risk takers*.

Koglin (2013) carried out a survey study in Stockholm and Copenhagen among cyclists. He found that cyclists in both cities experience motorised traffic as the mode of transport that creates most problems for them. Furthermore, other cyclists are also regarded as problematic. This, according to Koglin (2013), has to do with the lack of space for cyclists in the cities. Cycling is also seen as fast and efficient by the cyclists in Stockholm and Copenhagen, even though a higher percentage of cyclists think that in Copenhagen compared to cyclists in Stockholm and quite a high percentage of the cyclists in both cities experience stress while cycling. Furthermore, the majority of cyclists in Copenhagen view the planning for cycling as

positive, whereas the majority of cyclists does not so in Stockholm. This could also has to do with the better bicycle planning in Copenhagen compared to Stockholm. Moreover, in Copenhagen the majority of cyclists feel prioritised in traffic, which is not the case in Stockholm. Koglin's (2013) results show that in cities with good infrastructure for cycling and a good planning system the perception of the cyclists is more positive than in cities where the planning for cycling is not as well developed.

When analysing factors of importance, Lindelöw (2009) finds habits but not attitudes being of great importance. Besides this reference no other studies were found on analysing the importance of habits when it comes to cycling.

4 Socio-economic factors

Handy & Xing (2011) found that age is not significant for bicycle commuting and regarding propensity to cycle to work Wardman et al. (2007) found no significant effect of age. Carse et al. (2013), however, identified age as a main factor associated with modal choice for shopping.

The importance of gender on propensity to cycle might depend on where the study is carried out. Handy & Xing (2011) who base their conclusions on travel surveys in six small cities in the US report on gender being a significant socio-demographic variable. Females are substantially less likely to bicycle commute than males. Heinen et al. (2009) who also mainly base their literature study on US studies conclude that women bicycle shorter distances than men. Carse et al. (2013) present results indicating gender not being significant but being a female had a large contribution to explaining car travel. Heinen et al. (2013), a study, where also literature from the Netherlands is included, conclude that in countries with low cycling rates men tend to bicycle more; but in countries like the Netherlands and Belgium with higher cycling rates, cycling is also popular among women. In Börjesson & Eliasson (2012) gender was not a significant variable i.e. the value of time does not differ between men and women. This is supported in Wardman et al. (2007) who concludes that there is no significant effect on propensity to bicycle to work due to gender. Sick Nielsen et al. (2013) interestingly finds gender playing a role but in a different way than the studies in the US i.e. the study in Denmark finds that being a female contribute to increased likelihood of cycling.

Sick Nielsen et al. (2013) report on more education being related to higher probability to bicycle and higher education being related with longer cycling distances. Santos et al. (2013) also conclude that number of students at universities and further education per 1000 residents is positively related to shares of public transport, motor cycle, bicycle and walking. On the contrary Carse et al. (2013) report on education as a main factor (but not significant) associated with car travel to work (in general and also for shorter distances < 5km), for shopping and for leisure travel.

Handy & Xing (2011) report on income not being significant for bicycle commuting. Heinen et al. (2009, 2013) argue that the relationship between cycling and income is very unclear, it seems to have a lot to do with status, if it is a country where everybody has an own bicycle, etc. Wardman et al. (2007) also report on a weak effect on propensity to cycle to work due to income level. Sick Nielsen et al. (2013), however, report on higher income being related to less probability to cycle; having high personal or household income are related to less cycling. On the contrary, higher income is related to longer cycling distances. Other notable findings concerning income was found by Mendolia et al. (2014). They show that socio-economic factors also play a role in the modal split. Higher income per capita result in higher percentages of commuter journeys made by car and less by bike or foot (Mendolia et al. 2014).

In a study by Lee et al. (2014) the bicycle mode choice was analysed with a multi-level analysis that consider both the individual-level variables and neighbourhood-level variables. The main data source used was the 2006 Household Travel Survey in Korea. Results show that socio-

economic characteristics, gender, income, occupation, vehicle ownership, and housing type have statistically significant correlations with the bicycle mode choice, furthermore that shorter travel distance increase bicycle use. It also shows that high level of mixed land use results in even more bicycle travel. They therefore conclude that it is more effective to mix land use than it is to increase residential density (Lee et al. 2014).

5 Distance and time

The importance of distance when it comes to impact on cycling thus increase in trip distance results in lower share of cycling in mode choice, is well supported by many studies (Delmelle & Delmelle 2012; Handy & Xing 2011; Lindelöw 2009; Heinen et al. 2009; 2013). Heinen et al. (2009; 2013) bring up that some studies argue that self-selection is at stake as commuters by bicycle tend to live closer to work that other types of commuters. The authors also found a gender difference; women bicycle shorter distances that men. Sick Nielsen et al. (2013) elaborated on two models: Model 1 explains the probability of cycling and Model 2 explains distance bicycled. For the first model it turns out that flat terrain, short distance to retail concentrations, population and network connectivity within 1.5 km contribute to increased likelihood to cycle. But an important result is that too short distances are not favourable for cycling; *favourable conditions for walking* (retail jobs per resident and network connectivity within 500m) and PT (train station within 1000m and number of bus and train departures within 500m) seem to be *competitive to cycling*! For the second model it turns out that long distance to large retail concentrations, high population density and high network connectivity (the latter two ingredients convenient for walking) are related to *short daily cycling distances.*

Schoner et al. 2015 show that longer commutes decrease possibility to cycle but does not seem to affect frequency of cycling, suggesting that cyclists have a preferred cycling distance (Schoner et al. 2015).Frasie et al. (2010) identified in four studies that short distance to school as a predictor of active travel, cycling or walking, to school (Frasier et al. 2010).

In their study, Börjesson & Eliasson (2012) found lower value of time for cyclists with long distances (comprising only cyclists), and argue that this might be due to self-selection. Another finding is that the value of time does not differ between men and women. The study also presents results showing cyclists' value of travel time savings being high thus supporting the hypothesis that the reason for the higher value of saving cycling time is due to cycling being more onerous than other modes. Cyclists also seem to value other improvements highly, such as separated bicycle lanes. The authors conclude ".. the valuations of improved cycling speeds and comfort are so high that it seems likely that improvements for cyclists are cost-effective compared to many other types of investments, without having to invoke second-order, indirect effects." (Börjesson & Eliasson 2012:673). Sick Nielsen et al. (2013) present results where cycling is correlated with time costs thus indicating that high cycling speeds are related to longer cycling distances. As presented above Heinen (2009, 2013) point out attitude to be of greatest importance for cyclists regarding affecting modal choice but also list distance, costs and travel time of the journey as other important factors, after attitude.

6 Incentives, car ownership and parking

Wardman et al. (2007) report on payments for cycling to work being found to be highly effective with a £2 daily payment almost doubling the level of cycling. Also Heinen et al. (2009, 2013) report that if employers offer financial support for cycling the individual will be positively influenced to cycle. However, Handy & Xing (2011), find that incentives offered by employers is not significantly associated with bicycling.

Handy & Xing (2011) report on high parking costs being positively associated with bicycle commuting. In their study, parking costs, turned out to be more important than distance. Carse et al. (2013) also report on free parking at workplace being significant and one of the largest contributions to explaining car travel to work. They also found it being significant and the largest contribution to explaining short travel trips (<5km) to work. Together with facilities for other modes and free public transport pass, Heinen et al. (2013) report on free car parking provided by the employer negatively affecting cycling frequency. Delmelle & Delmelle (2012) report on increase of car parking cost having a great impact on mode choice and owning a parking permit increase car usage by 36%. They argue that availability of lower-cost parking permits is an enabler of shorter distance car commutes. They also mention the importance of understanding policy implications due to not coordinating parking strategies in adjacent areas which may undermine efforts to use parking strategies as a mean to increase non-motorised or public transportation.

Carse et al. (2013) report on car ownership being one of the largest contribution to explaining car travel to work. Also the factor with the strongest contribution to explaining short work trips by car (< 5km), being a main factor associated with modal choice for shopping and a predictor of modal choice for leisure travel. Heinen et al. (2009, 2013) also report on car ownership having a strong negative effect on cycling mode share, but again reflecting on differences between countries; according to some studies high social status reduces probability of cycling. Santos et al. (2013) also concluded that car share increases with car ownership and GDP per capita. However, Handy & Xing (2011), do not find car ownership being significant. Conversely, research by Haugen (2012) has shown that factors, such as density, only affect travel behaviour and use of different modes of transport to a rather small degree. Haugen concludes that car ownership contributes to a major degree on whether a car is used or not and thus whether one uses the bicycle or not (Haugen 2012).

7 Network layout and facilities

Heinen et al. (2009) report on different findings in different reports regarding whether the assumption "higher densities and mixture of functions" should promote cycling. Sick Nielsen et al. (2013) conclude that urban form and location affects cycling and cycling distances – but the relation is complex. The use of the bicycle is sensitive to whether density, service and land-use diversity occur within a short convenient walking distance or further away. Regional location, access to train and buses and level of service affects cycling. Carse et al. (2013) concludes that longer commuting distance is significantly associated with travelling with car.

Heinen et al. (2009) refer to some comparative analyses indicating that countries with more cycling facilities have higher modal split share of cycling. The authors, however, point out that it remains unclear whether the presence and continuity of bicycle infrastructure actually increase bicycle mode share or cycling frequency. They argue that it might be so that the presence of infrastructure results in more cycling, but also that a higher cycling frequency could stimulate the construction of bicycle infrastructure. The authors also refer to different results in different studies regarding the importance of delays on cycling. As the authors point out this might be due to whether the study is based on stated or revealed preferences. Most studies, however, assume that lower motorised speeds and lower levels of traffic have positive effects on bicycle mode share. Krenn et al. (2015), in their study analysing characteristics that differ between "actually taken route" and "shortest possible route", show that the length of bicycle infrastructure and especially the existence of separated cycle path was positively related to actually used route. Main roads (a main road with no infrastructural facilities for cyclists i.e. no bicycle path or lane) i.e. cyclists have to cycle in mixed traffic with motorised traffic, was negatively related to actually used route. Santos et al. (2013) in their very extensive study based on 2001 and 2004 modal split shares in 112 medium-sized European cities report as one of the main conclusions that bicycle share for journeys to work increases with length of bicycle network in the city. Wardman et al. (2007) developed a model that combines Revealed Preference (RP) and Stated Preference (SP) data to describe factors influencing the propensity to cycle to work. Regarding cycle facilities, the results show that a completely segregated cycleway was forecasted to have the greatest impact, but even the unfeasible scenario of universal provision of such facilities would only result in a 55% increase in cycling and a slight reduction in car commuting.

Pucher et al. (2007) shows that one of the most important factors that created safe cycling in all of the cities is identified as cycling facilities separated from heavily travelled routes. The study claims that the success of cycling policies in the three countries is thanks to coordinated implementation of multi-faceted, self-reinforced policies (Pucher et al. 2007). Pucher et al. (2008) also made a comparison of the above mentioned cities to determine what makes cycling attractive in these cities. As above they found that separating the bike infrastructure from the motorised traffic is an important factor in increasing cycling. But they also find that this is not the only contributing factor in creating attractive cycling facilities. Different quality-heightening efforts, such as bike parking, integration with public transport, traffic education and training, matters in creating safer and more attractive systems (Pucher et al. 2008).

Handy & Xing (2011) report on that racks and showers close to work do not significantly influencing bicycle commuting. Neither Heinen et al. (2009) find that facilities at work (shower, parking facilities, etc.) would affect bicycle mode share or cycling frequency. In contrast, Heinen et al. (2013) show that having access to clothes changing facilities and presence of bicycle storage inside increases the likelihood to be a cycle commuter. In Wardman et al. (2007), outdoor cycling facilities at work were found to be equivalent to 2.5 minutes spent cycling; indoor parking facilities being equivalent to 4.3 minutes spent cycling and shower/changing facilities in addition to indoor parking facilities being equivalent to 6.0 minutes spent cycling.

8 Landscape, weather, climate and self-selection

Heinen et al. (2009) report on studies arguing for the importance of the natural environment i.e. landscape, weather, and climate while others argue that personal factors play a larger role than the environmental factors. According to Heinen et al. (2009) studies are, however, uniform regarding less bicycle use during winter and bad weather but that there are national and regional differences on the magnitude. The studies also show that commuters tend to be less influenced by temperature than other cyclists and again there are regions that still have a high bicycle share despite low temperatures like regions in Canada. In their study, Krenn et al. (2015) analysed characteristics that differ between "actually taken route" and "shortest possible route", the presence of "green and aquatic areas" was positively related to actually used route while topography (slope) was negatively related to actually used route. Heinen et al. (2009) support that latter with referring to some studies indicating that slopes have a negative effect on bicycle use.

Shoner et al. (2015) saw suggestions of self-selection effect, where people who prefer living near bicycling facilities preferred to cycle. Significant factors in the built environment were job accessibility and bike lanes (Schoner et al. 2015). Continuing in that line of thought, Krenn et al. (2015) found that regular cyclists lived in a more bicycle-friendly neighbourhood than non-cyclists. "It is not known whether cyclists deliberately choose bicycle-friendly living neighbourhoods, or if improvements to the bicycle-friendliness of a region increase the cycling rate" (Krenn et al, 2015:457). To answer the latter, measurements before and after changes in urban design, are required". Heinen et al. (2009, 2013) also argue that self-selection might be at stake when discussing the results on increase in trip distance resulting in lower share of cycling in mode choice. Thus, commuters by bicycle simply choose to live closer to work than other types of commuters. Also Handy & Xing (2011) argue that self-selection might be at stake when reporting on Bike Community Preference being one of the most significant contributors to bicycle commuting according to magnitude of odds ratio. Börjesson & Eliasson (2012) also argue that the result showing lower value of time for cyclists with long distances (comprising only cyclists) might be due to self-selection. In this self-selection context it might be worth mentioning Chatmans' (2014) objection to earlier cross-sectional studies not being able to recognise that individuals with different preferences may react differently to the same built environment. With this point of departure Lindelöw et al. (2016) presented findings regarding walking that indicated the importance of taking individual's heterogeneous preferences regarding residential and modal choice into consideration rather than as control variables that alter the estimated effect of the built environment.

9 Conclusion

The research in the area of bicycle planning, policies and land use consists of many different types of studies, but even though the studies are carried out with different methods and varied aims, they mostly point to the same results. The literature largely consists of comparisons of successful and less successful examples of bicycle oriented planning around the world. What appears to be common among the examples with high amounts of cycling is the multi-layered support for bicycle focused planning. Both local, regional and national policies are important to create good conditions for bicycle planning. Cities like Copenhagen and Amsterdam do not only have a strong history of bicycle oriented city planning, but also relatively strong national support in shape of policies and planning. It seems that cities and countries that have a large part of trips made by bicycles are successful in creating both good policies and planning for the bicycle. From that one can conclude that in order to create good possibilities for cycling, the notion, that cycling is good, has to have support from all layers of government. This support has to be both in shape of good policy documents, but also in shape of financing, since building bicycle infrastructure costs money.

Furthermore, it has been shown in research that the organisation of transport and urban planning can have a positive or negative impact on planning for cycling. Also aspects that planners might not influence have an impact on whether the cities develop a fruitful planning system that favours cycling instead of, e.g., motorised traffic. These aspects could be historical, cultural or political.

It is also worth noticing that time is one of the things that affect how successful the strategies are. None of the studies really investigate this subject on a deeper level, but it seems as if all the examples with high amounts of bicycle trips also are cities with a long history of bicycle friendliness. Thus, having strategies that have a longer span also have a greater potential in being successful. The importance of national and regional strategies come into play again here, since these tend to span over a longer period of time and often have a more comprehensive view.

Another important factor in increasing cycling trips that has been shown in several studies analysed in this report are the competiveness of the bicycle in relation to the car. In order to make the bicycle more attractive as a mode of transport, the attractiveness of the car has to be decreased. For example Rietveld et al. (2004) found that competitiveness of bicycle in relation to the car was the most important policy factor. Examples of measures that raise the competiveness of the bicycles that is given in the literature are: parking charges, oil prices, integrating cycling with public transport, separating bicycle lanes from roads and attractive bicycle parking. A strategy that does not take in account other aspects than cycling, might therefore not be as successful as one that tackles the transport system at several stages. Strategies that address motorised traffic as well as cycling have potential to increase the relative attractiveness of the bicycle more than those that only address cycling.

Arguably the most interesting result is that regardless of how well designed and executed a transport policy is, the built facilities seem to be the factor with the greatest correlation to number of bicycle trips. The problem with this conclusion is that the research is made as case studies and not comparing before and after-studies, thus it is not possible to determine if this is an effect of the built environment or if it's a self-selection effect, as discussed above.

The studies in this literature review are often surveys with the aim of catching stated or revealed preferences, but besides identifying factors that seem to influence modal choice, what may be said regarding effects on cycling frequency?

For some factors there is consistency among studies whether there is indication of being positively (e.g. high car parking costs) or negatively (e.g. long commuting distances) associated with cycling. While for most factors there are big differences between the studies. The location of the study may be an explanation to these differences i.e. if the study involves cities in the US or Australia, where the share of cycling often is very low as compared to if the study is carried out in the Netherlands. Another explanation could be that most studies are quite limited regarding participants, but also regarding number of factors surveyed.

As pointed out in Heinen et al. (2009) most studies are based on surveys targeting cyclists' and non-cyclists' preferences regarding cycling. But to be able to say anything about factors' impact on cycling frequency then surveys must be based on before- and after studies i.e. assessing the effect when different factors are changed. The authors bring up the example that bicycle infrastructure seem to matter, based on preferences, but there are no results regarding the connection between bicycle infrastructure and bicycling frequency. Preferences and attitudes are probably very important but as the authors argue, we must get better insight into how these preferences and attitudes may influence mode choice and bicycle frequency. The authors continue to pin point the issue of limited number of factors surveyed; as most of the referred studies only consider few factors it is difficult to assess factors' relative importance.

The study by Carse et al. (2013), describing what characterises those that bicycle or not bicycle, is also not a before/after study that actually looks into what happens when the factors (characteristics) change. Thus, it is not possible to draw any conclusions on whether a person that previously lived further away from work actually would start cycling when moving closer to work, etc. Nor based on the study by Börjesson & Eliasson (2012) that looks into how cyclists value time and how they prefer separated bicycle lanes compared to cycling in mixed, it is possible to conclude that changes in the bicycle infrastructure resulting in reduced travel times or more separated bicycle lanes actually would affect the level of cycling. It is similarly with the study by Krenn et al. (2015). This study reports on what you prefer as a cyclist (bikeability) but it is not possible to draw any conclusion on contributing to cycling i.e. cause of cycling.

The importance of attitudes to cycling was brought up in many studies and in the literature review by Heinen et al. (2009) attitudes was pointed out as the perhaps most important factor when analysing reasons for commuting by bicycle. Also Handy & Xing (2011) point at "soft strategies" as attitudinal changes may have a measurable impact on cycling. Heinen et al. (2009, 2013) recommend that future research should focus on both subjective and objective values.

10 Future research

Many studies wind-up by expressing a need for evaluation and that it is not sufficient to know which factors people express as being important or factors that differ between cities with high and low levels of cycling. Handy & Xing (2011) phrase it in the following way: ”Although this study provides direction as to which factors are likely to make the most difference – which levers to pull, so to speak – planners can only be sure about the effectiveness of their strategies when they try them and evaluate them.” (Handy & Xing 2011:109). Therefore, future research should also include evaluation measures of bicycle policies, politics, programmes and infrastructure. Without good evaluations measures and methods, it can be very difficult to draw proper conclusions what actually affect bicycling and bicycle use in cities. Here before- and after studies could be very valuable in evaluating different types of infrastructures.

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