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Published in:
Danish Journal of Geoinformatics and Land Management

Publication date:
2011

Document Version
Publisher's PDF, also known as Version of record

Bike Infrastructures and Design Qualities: Enhancing Cycling

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Abstract
Decisions on transportation projects are typically – alongside the project costs – based on the potential for the project to contribute to broad public policy goals. Information on how specific design qualities enhance cycling will help decision makers to develop better and more cost-effective bike infrastructures. This article aims to present findings of the research project titled Bikeability – funded by the Danish Research Council. The overall purpose of the Bikeability project is to investigate and document relations between cycling motivation from different socio-demographic groups and distinct design characteristics related to the urban environment and the bike infrastructure. The part of the project described in this article concerns an in-depth case study of three bike infrastructures with distinct typologies – Vestergade Vest/Mageløs in Odense; Hans Broges Gade in Aarhus and Bryggebroen in Copenhagen. The main element of the case studies is a questionnaire amongst users of the three infrastructures allowing the determination of socio-economic characteristics of the users and effects of the infrastructure in terms of the use of bike. Furthermore, the users were asked to assess the infrastructure project as well as to describe what specific design element primarily motivated them to travel by bike. The findings highlight the critical role of fast connectivity and fast bike lanes in motivating cyclists to ride their bikes more often. It also indicates that it is challenging to ensure the perception of safety in shared-used spaces. These are findings that should be taken into consideration by architects, planners and engineers when designing bike infrastructures. Bridging research and policy, the findings of this research project can also support bike friendly design and planning, and cyclist advocacy.

Keywords
Bicycle infrastructure, Bikeability, Urban Design, modal split

Introduction

Decisions on transportation projects are typically based on the potential for the project to contribute to broad public policy goals. In the Danish context, the primary focus for the bike infrastructure projects is to provide good transport facilities for non-car users and especially in the

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latter years to motivate car users to choose to ride a bike instead, i.e. changing modal split from private car to bike – particularly when it comes to the intra urban trips. Despite the fact that Denmark is internationally know as a cycling nation and thus have a tradition for prioritizing bike infrastructure, there is in general a limited knowledge regarding the likely effects of bike infrastructures – except those related to the safety effects of bicycle paths, see e.g. Jensen (2008). This reflects a negligence of the importance of performing evaluations of bike infrastructure projects documenting the effects on cycling of given interventions, which specifically is reflected in the fact that before-after counts of cycle traffic are very rarely performed. Consequently, in terms of promoting the use of bicycle (instead of car) designers and planners are in need of knowledge, which helps them to identify the most cost-effective bike infrastructure for a given context.

This article aims to present initial findings of the research project titled Bikeability – funded by the Danish Research Council – concerning the investigation of possible relations between cycling motivation from different socio-demographic groups and distinct design characteristics. Specifically, the article describes the results from an initial case study of three bike infrastructure projects. The case study provides a more detailed insight in what design characteristics are relevant for cyclists when choosing the bike as the mean of transportation and how cyclists do evaluate a cycling infrastructure based on these characteristics. The outcomes of this research may be propagated and used by decision-makers, urban designers, city planners and traffic engineers committed to promoting cycling.

Exploratory research

Previous research has been developed dealing with several aspects regarding cycling. However, there is a lack of scientific based studies exploring the role of design characteristics to enhance cycling. Therefore, the current publications do not provide foundation of knowledge to better understand the influence of design characteristics upon individuals` choice to ride a bike. The Ministry of Transport, Public Works and Water Management (2007) published the report 'Cycling in Netherlands' where five built environment aspects are presented as key qualities when developing a bike infrastructure. The aspects are coherence, directness, attractiveness, safety, and comfort. However, the publication is primarily based on practical experiences and non-scientific reflections.

Due to lack of former research aiming to understand possible relations between cycling motivation and design characteristics, the study presented in this article was designed as exploratory and aiming to identify parameters related to the infrastructure that are of relevance in order to promote cycling. This exploratory study makes a difference by aiming to investigate the possible relations between design characteristics and cycling motivation. Moreover, this study contributes directly to the body of knowledge, highlighting perspectives of the cyclists upon the relevance of design characteristics to motivate riding a bike as a basis for further research and cycling advocacy. Individuals have several motives for riding a bike. Based on their experiences from using the bike infrastructures, cyclists are likely to have better insight, when it comes to specific needs in regards to the design of the infrastructures that urban designers and decision-makers might not be aware of. Consequently, performing interviews and questionnaires among cyclists is – in the absence of before-after evaluations of effects – the best source for retrieving knowledge upon the effects of specific bike infrastructure interventions.

Analysis of bike infrastructure performance through the lenses of cyclists

The bike is an important and strategic mean of transport in urban areas, especially in the Danish context where municipalities since the sixties have been implementing many bike infrastructure projects to increase cycling. In Danish cities, the traffic system consequently already offers a large amount of bicycle infrastructures – e.g. bicycle lanes with special pavement, bicycle tracks, green corridors, shared spaces – and cycling policies, campaigns and cyclist friendly traffic regulations.

Despite the fact that the Danish cities to some extent have been equipped with bicycle infrastructure, the proportion of transport performed by bicycle has declined for several years. According to the data from the national traffic index, the use of bicycle traffic has declined by 14% from 1990 to 2009. However, it remains a national and local goal to promote cycling. This is basically down to the fact that turning trips from cars to bicycles has the potential to effectively reduce climatic and environmental strains stemming from road traffic as well as to improve public health. Furthermore changing modal split by transferring trips from car to bike may effectively reduce congestion problems in urban areas.

In this context, a need to measure the impact on travel behaviour of new bike infrastructures implemented in urban areas emerges. Both national and local authorities and planners are in demand of studies documenting effects and costs of bicycle infrastructure interventions (Hansen 2010; Ruby 2010) Such studies are in demand, as they will enable the authorities to identify the interventions that may bring about the most cost-effective improvements to the use of bike and the safety of cyclists. Having three case studies, this study expands on how these assessments can be done.

The case studies and selection criteria

The research was structured as a case based study where three bike infrastructures with distinct typologies – Vestergade Vest/Mageløs in Odense (shared-use space in the core of the city); Hans Broges Gade in Aarhus (an extension of a bicycle route linking the suburbs to Aarhus Central station) and Bryggebroen in Copenhagen (a bridge for bicyclists and pedestrians crossing the harbour). Please refer to Figures 1, 3 and 5.

Critical analyses were done to select the particular three case studies for this study. Their inclusion depended to a great extent on four criteria: recently implemented infrastructures (less than 5 years); relevant cases for the development of urban mobility strategies; distinctively different typologies between the cases; and located in municipalities which were interested in and willing to share detailed information about the interventions.

The infrastructures should be less than 5 years old, presenting a reasonable time to individuals that ride their bikes there to remember their travel habits before and after the interventions.

Vestergade Vest/Mageløs

Formerly, Vestergade Vest/Mageløs had more than two hundred buses passing every day causing noise pollution, air pollution and also inhibiting a more friendly space for pedestrians, cyclists and other potential activities in the public space.

Figure 1: View of Vestergade Vest/Mageløs, September 2010

After the urban transformation, the public space changed its profile completely – enhancing walking, cycling, shopping, eating, playing, etc (Figure 1). The urban transformation has been enhancing a discussion about public domain and also has regenerated the image of Vestergade Vest/Mageløs towards a lively spot (Andrade et al., 2011).

The intervention in Vestergade Vest/Mageløs was completed on the 19th of August 2010. The street formerly crowded by motorized vehicles was transformed into a shared-used space for pedestrians, cyclists and a future central electrical bus ring – being allowed the access for cargo-carrying motorized vehicles. All the buses were rerouted to parallel streets nearby. (Odense Municipality 2009).

The new street layout seeks to promote walking, cycling, shopping, playing and eating. It also offers the opportunity to promote products outside shops and allows outdoor seating for cafes and restaurants.

The flow of cyclists and pedestrians at Vestergade Vest/Mageløs moves in multiple directions with the main flow of cyclists through the middle of the street.

Sidewalks are reserved solely for pedestrians with the lane in the middle of the street shared equally by pedestrians and cyclists.

Traffic flow in the morning is relatively calm as no pedestrians are congesting the space allowing cyclists to flow freely through. Cyclists are focused and know exactly how to navigate and avoid other cyclists (Figure 2).

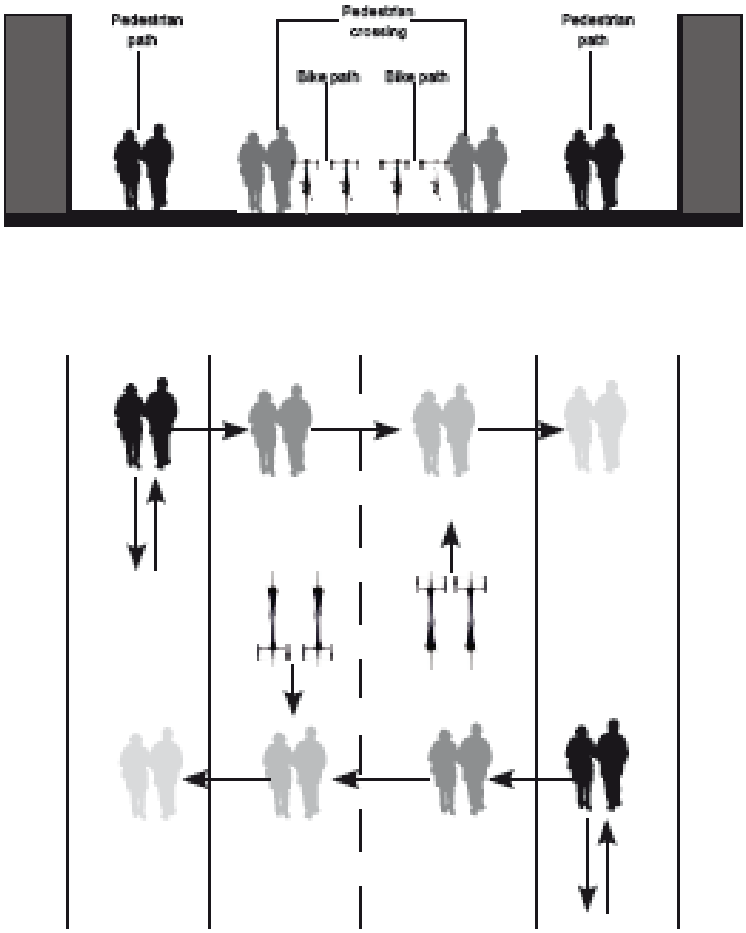

Figure 2: Section and Plan of View of Vestergade Vest/Mageløs.

Hans Broges Gade

Hans Broges Gade is located within the Aarhus` inner city ring, in a dense neighbourhood composed by block structures up to five stories high from the early 20th century. The street serves as an important link between the suburbs and the core of the city. Moreover, there is a pedestrian flow of mostly local residents that use the local commerce.

The purpose of the intervention at Hans Broges Gade was to improve a bicycle route connecting the southern suburbs of Holme to the centre of the city, in order to become one of the seven main bicycle corridors of the bicycle network plan (Andrade et at. 2011).

Hans Broges Gade used to be a street with broad lanes for motorized vehicles and car parking facilities in both directions just next to the sidewalks. There were only bicycle tracks at the first 100 meters of the street in the side facing Marselis Boulevard. Along the rest of the street, cyclists had to ride their bikes on the outside of the rows of parked cars together with motorized vehicles, especially busses.

Figure 3: View of Hans Broges Gade, September 2010.

With long blocks of up to 150 meters, cyclists with their bikes parked on the sidewalk had difficulty to access the road because of the dense row of parked cars. During the field observation several elderly residents mentioned it used to be unsafe to walk on the sidewalks because cyclists preferred to ride their bikes on them.

In order to give space to implement bicycle tracks in both directions of the street, one of the car parking rows was removed.

The flow of cyclists and pedestrians at Hans Broges Gade is going in both directions on either side of the road. Looking south down the streetscape, the sidewalk is divided into three spaces. Beginning from the building across, there is a space for bike parking and shop signs. The pedestrian path (pavement) lies directly next to the bicycle track divided by a small drainage gutter. The grass area separates cyclists from the parked cars and the street. On the opposite side of the street, there is no car parking and no grass area dividing the cars from the cyclists (Figure 4).

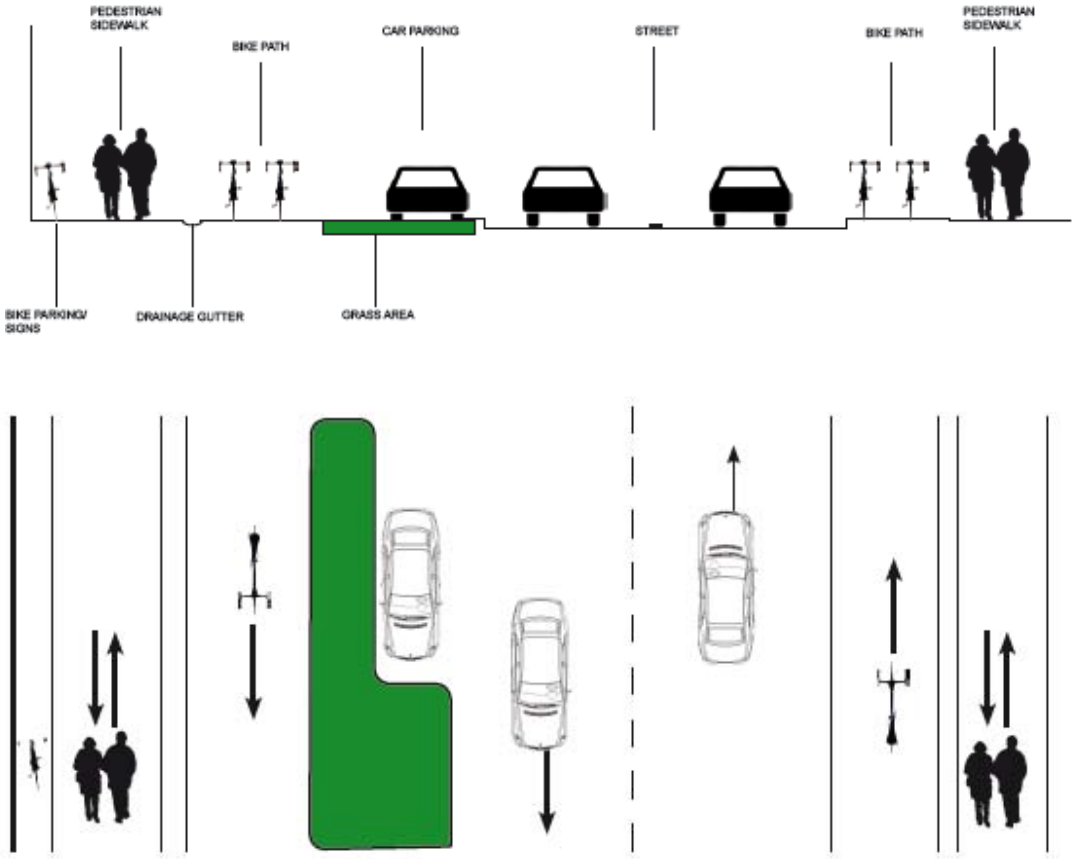

Figure 4: Section and plan of Hans Broges Gade.

Bryggebroen

The first exclusively dedicated pedestrian and cyclist bridge of Copenhagen – Bryggebroen – was inaugurated in 2006.

The construction of Bryggebroen improved the accessibility between the two sides of Copenhagen Harbour. Bryggebroen links the two sides of Copenhagen Harbour and complements the other three connections across the Copenhagen Harbour. Differently from the other connections, Bryggebroen is exclusively dedicated for cyclists and pedestrians. On the north direction, there is Langebro – 1 kilometre from Bryggebroen – and Knippelsbro – 2 kilometres from Bryggebroen. On the south direction, there is Sjællandsbroen which is situated 3 kilometres from Bryggebroen (Figure 5).

Bryggebroen is a 190 meter long, six and a half meter wide, swing bridge connecting Kalvebod Brygge over Havneholmen to Islands Brygge. The flow of cyclists and pedestrians at Bryggebroen is going in both directions on either side of the bridge and at either ends of the bridge. Looking at a section of the bridge it is divided into three spaces.

Figure 5: View of Bryggebroen, September 2010

Beginning from the left there is a two way pedestrian path going in both directions, alongside this is an 80 centimetre high concrete girder that separates the two-directional cycling track from the walking path without obstructing eye contact between passing pedestrians and cyclists (Figure 6).

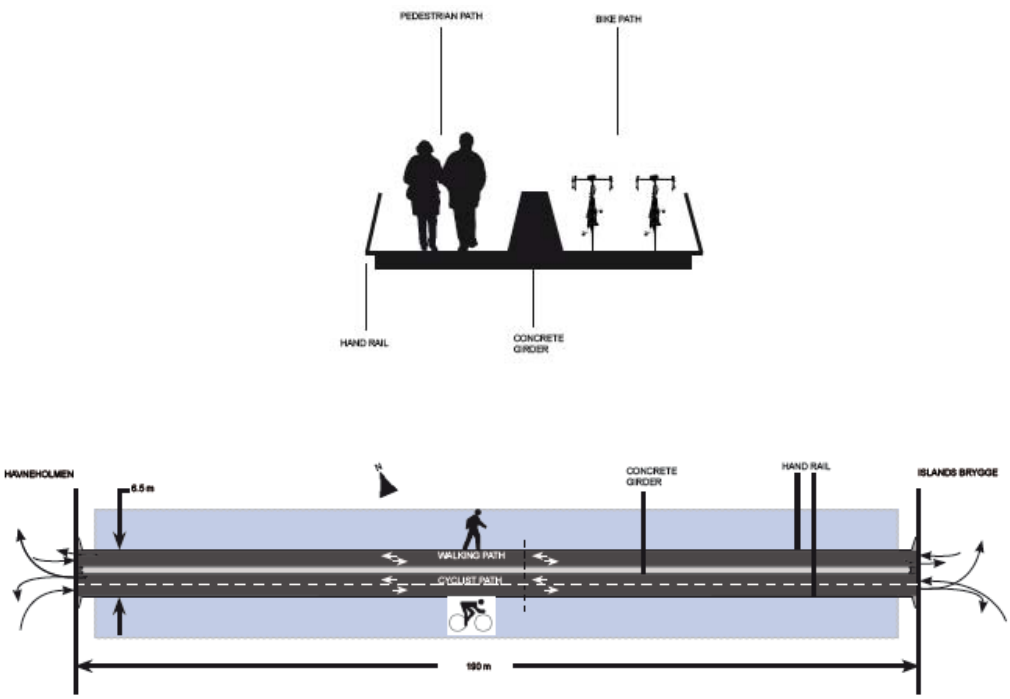

Figure 6: Section and plan of Bryggebroen.

Data collection and analysis

The project applies a multi-disciplinary approach to research on bike infrastructure, correlating quantitative determinants and qualitative knowledge types. Both primary and secondary data have been employed. For each infrastructure, the data was collected through; a questionnaire based on a web survey, a counting of cyclists, local observations, diaries of the daily flow and atmosphere and image collection, interviews and exchange of e-mails with key actors, reviews of reports, official documents, newspaper articles and press releases. Statistical tests were applied to identify possible relations between socio-demographics (independent variables) of the sample and the respondents` answers from the questionnaire (dependable variables). According to Denzin (1978), a triangulation method can be defined as 'the combination of methodologies in the study of the same phenomenon'. Considering the geometric characteristics of a triangle, it can be assumed that distinct viewpoints allow for greater accuracy.

Questionnaire design

The questionnaire was aiming to identify the demographic profile of the cyclists, the relevant design characteristics for the cyclists and to which extended the implementation of the infrastructure has enhanced cycling. Cyclists were asked to indicate which cycling infrastructure characteristics they had observed during their trip. They were also asked to evaluate the observed cycle infrastructure characteristics. In addition, respondents were invited to make comments about the infrastructure.

In order to develop the survey, journal articles and research reports in the area of urban cycling studies were reviewed to identify consistent infrastructure characteristics related to the improvements of presumed relevant aspects to the selection of the bike in daily traffic such as; safety, aesthetics, accessibility and fast connectivity (Pikora et al. 2003).

In order to analyse bicycle infrastructures through the lenses of cyclists, the questionnaire targeted the cyclists as potential respondents. Relevant questions in the context of cyclists perception and evaluation of cycling infrastructure are; 'what design characteristics do cyclists mostly observe/perceive while they are using the cycling infrastructure?' and 'how do cyclists evaluate these design characteristics?' It is important to identify what design characteristics they mostly perceive and how these characteristics influence their decision to ride a bike. Consequently, it will be possible to develop an assessment of a bike infrastructure based on the cyclists' perspective.

Taking into consideration social demographic characteristics – gender, age and educational level – the study also aims at better understanding how relevant socio-demographic variables are in relation to the individuals` perception of cycling infrastructures and to possible influential characteristics on the decision to ride a bike.

Flyer distribution, web survey and responses

It was decided to recruit the respondents by handing out flyers at each of the three locations. The flyers contained a link to website with the questionnaire, thus performing the questionnaire as a web survey in order not to delay the cyclists by completing the questionnaire at the site. For every studied infrastructure, the distribution of the flyers took place from 7am until 7 pm in one

weekday (Tuesday, Wednesday or Thursday) with good weather conditions (no rain or heavy wind) in the month of September 2010. From 7am until 7pm, flyers were offered to every cyclist riding a bicycle in the infrastructure in both directions. Alongside the distribution of the flyers, the counting of cyclists at the site was performed. For each of the cases, the web survey was available from the date of the flyer distribution until four weeks later.

The studied population and sample size

Respondents of the survey are cyclists that have at least once been riding a bike on the studied infrastructure. Despite of the consideration that part of the studied population would be unable to access the Internet, the Internet users are becoming more and more similar to the general population because the accelerated increase in Internet usage (Pastore 2001).

	Vestergade V. and Mageløs	Hans B. Gade	Bryggebroen
Cyclists counted (7am - 7pm)	6446	1251	7352
Flyers handed	1328	605	3020
Respondents	298	163	290

Table 1: Number of bike trips, cyclists, flyers handed out and number of respondents.

Data analysis

The data analysis aimed at better understanding the impact of the examined infrastructures upon the bicycling activity. Consequently, the data collected from the questionnaires were entered into the statistical software Statistical Package for Social Science (SPSS) for analysis. Statistical tests were applied to describe the results and to identify significant dependencies between variables.

The collected data from the web survey was analysed in four different stages and a distinct statistical treatment was applied. Firstly, the residential location of the respondents was spatially identified and then analysed in relation to its distance to the infrastructure under examination. At the second stage, descriptive statistics were applied to describe collected data and highlight singular characteristics and relevant patterns. Socio-demographic patterns of the respondents were identified at stage three and the distribution of the answers according to these patterns was implemented. Finally, the Chi2-test was applied to identify possible relations between socio-demographics (independent variables) and the variables originating from the web survey questions (dependable variables). Considering the nature of the studied variables – the majority of them are nominal.

Results

Socio demographics

In comparison to Hans Broges Gade and Vestergade Vest/Mageløs, respondents from Bryggebroen have the highest average age with 32% of them between the ages 31 to 40 years. The average age of the respondents can be related to their educational level. Respondents with the highest

average age at Bryggebroen also have a higher educational level – 77% of them have a medium or longer high education.

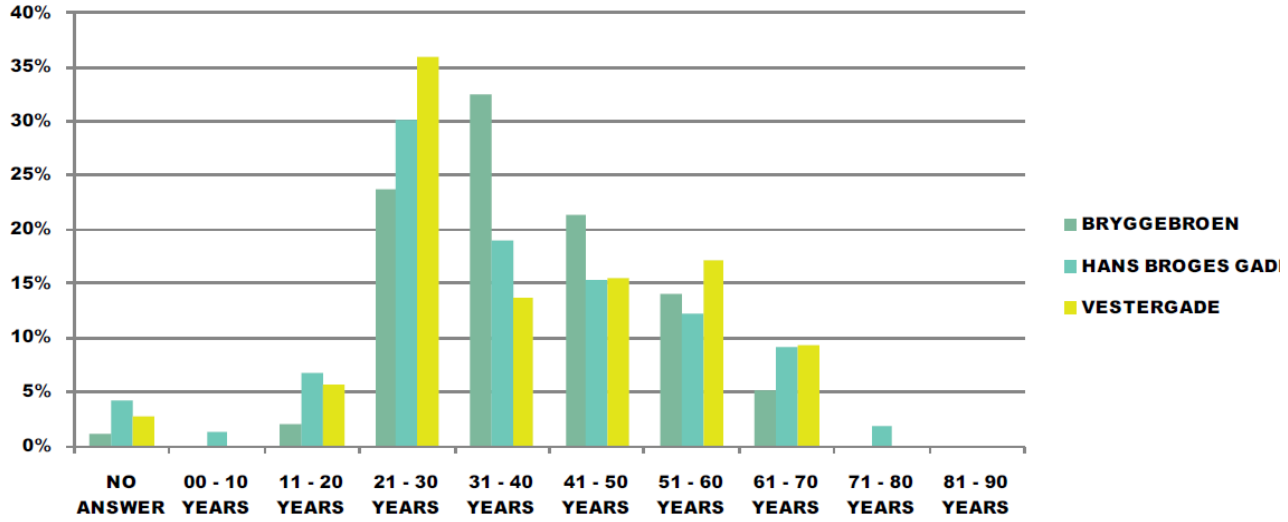

Figure 7: Distribution of the respondents by age

The distribution of respondents by gender is very balanced at Bryggebroen, where 50% of the respondents are males and 49% are females. 1% of the respondents did not answer that question. The other two infrastructures present a larger difference between males and females.

At Hans Broges Gade, 52% of the respondents are male and 44% are female. Finally, 54% of the Vestergade Vest and Mageløs` respondents are male and 44% are female.

There are several studies about gender and cycling behaviour developed outside Denmark and the results highlight that gender has a predominant role over the individual decision to ride a bike (Moudona et al. 2005).

However, the results from the three web surveys developed in this research indicate that there is not a significant relationship between gender and how often an individual ride a bike. One of the reasons that gender is not a predominant factor in Denmark could be that bike culture is so wide spread across the country or at least in the largest Danish cities – Copenhagen, Aarhus, Odense and Aalborg.

Main trip purpose

Bryggebroen has the largest amount of respondents riding their bikes for commuting purposes. Amongst Bryggebroen`s respondents, 70% ride their bikes at Bryggebroen to go to/from work and 8% to go to/from study.

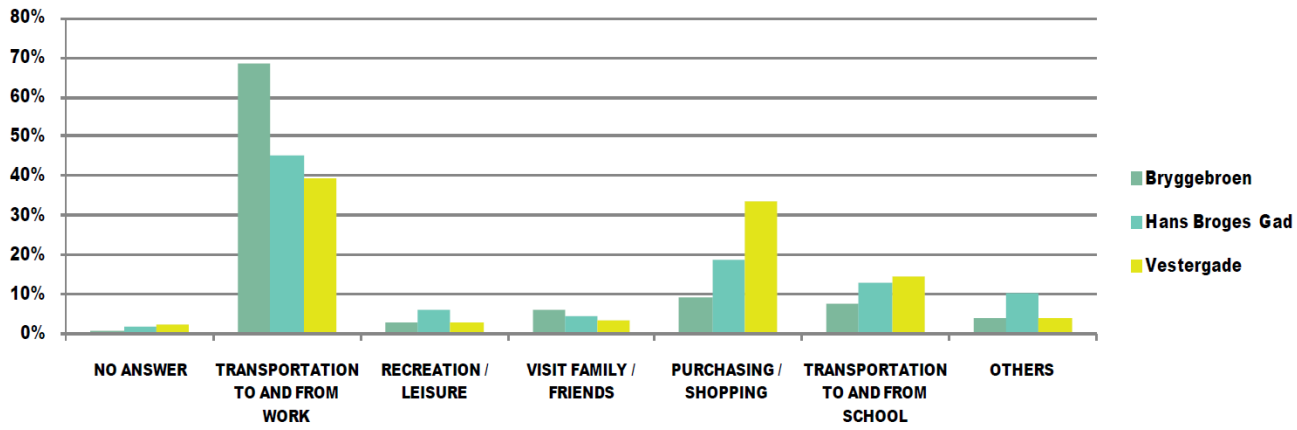

Figure 8: Distribution of the respondents in accordance to the main trip purpose when riding a bike at the infrastructure.

In contrast to Bryggebroen, respondents from Vestergade Vest/Mageløs and Hans Broges Gade represent a more balanced distribution of trip purposes. 39% of the respondents from Vestergade Vest/Mageløs have said they ride a bike to go to/from work and 13% are going to/from their study. There is still a high percentage of commuters, but the infrastructure also has a representative amount of respondents (33%) riding their bikes to go shopping. This is most likely due to the fact that this particular site is located close to – not to say is part of – the commercial district of Odense.

Design elements influencing to bike more often

Comparing the results from the three web surveys, the implementation of Bryggebroen influenced the largest quantity of respondents (30%) to start to ride a bike more often. In this context, it is important to take into consideration that the opening of Bryggebroen created a new link between the two sides of Copenhagen Harbour.

When respondents – who started to bike more often after the intervention – were asked for their motivations, there was a different pattern of answers for the three infrastructures. 45% of Bryggebroen"s respondents said that fast connectivity was the main reason for them to start to ride a bike more often. Moreover, 91% of Bryggebroen`s respondents said to be satisfied with the design solution of the infrastructure in regards to fast connectivity. In comparison, only 38% of respondents from Vestergade Vest/Mageløs were satisfied with the new bike infrastructure. Here only 6% of the respondents indicated that the project had influenced them to travel by bike more often.

Enhancing fast connectivity, Bryggebroen has a dedicated high-speed lane connecting the two sides of the harbour. Vestergade Vest/Mageløs serve as a shared-used space, where cyclists need to negotiate the space with other transport modes during most of the day.
Despite the challenges faced by cyclists at Vestergade Vest/Mageløs, see below, the majority of respondents that started to ride a bike more often after the intervention have mentioned fast connectivity as a main factor. 33% of respondents were satisfied with the design solution in

regards to fast connectivity. In the case of Hans Broges Gade, respondents that started to bike more often after the intervention,which amounts to 12% of the respondents, have mentioned enhanced safety as the main reason.

Satisfaction with the infrastructure

While the proportion of respondents from Bryggebroen and Hans Broges Gade who were dissatisfied with the infrastructures was respectively 1% and 8%, the percentage of dissatisfied respondents was much higher (14%) for Vestergade Vest/Mageløs.

The different infrastructure typologies might have an influence in the result. In the cases of Bryggebroen and Hans Broges Gade the design solutions segregate the different transport modes and provide dedicated lanes for cyclists. The intervention in Vestergade Vest/Mageløs is based on the concept of shared- use space. Consequently, there are no dedicated bike lanes and the cyclists need to negotiate the space with the pedestrians. This is in parallel to the findings made by Jensen who argues for an understanding of 'negotiation-in-motion' as the descriptor of mobile multi-modal interactions in shared-space like environments (Jensen 2010).

The data collected from the bicycle counts, local observations and newspaper articles indicate that Vestergade Vest/Mageløs is perceived as a more challenging space to navigate, especially between 3pm and 5pm where there is a large amount of both cyclists and pedestrians sharing the same space. A shared-use space challenges the cyclists to learn how to negotiate their space with pedestrians and induces the cyclists to ride their bikes at a lower speed.

In general, the satisfaction of the respondents about the design solution of the infrastructures in regards to safety, conflict between travel modes, aesthetics and parking are similar to their satisfaction with the overall design.

Satisfaction with design solution with regards to safety

Objective safety describes the actual risk for road accidents or road injuries to occur, i.e. actual accidents or injuries related to site-specific exposure, while subjective safety is the individual perception of safety. The distinction is highly important as feeling unsafe may not result in accidents as the cyclists through their behaviour may compensate for feeling unsafe. On the other feeling unsafe may cause the road users to favour the use of car over the use of bike.

The case study covers the subjective dimension of safety, assessing the infrastructures according to the respondents` level of confidence in the design solution for the 3 different infrastructures in regards to safety when riding a bike.

The majority of the respondents from Bryggebroen and Hans Broges Gade were satisfied with the infrastructures design in regards to safety. However, 11% and 7% of the respondents respectively were very unsatisfied with the infrastructures in terms of traffic safety. At Vestergade Vest/Mageløs, half of the respondents were not satisfied with the infrastructure design with regards to safety. The negative response could be partially influenced by the profile of the infrastructure as a shared-use space. Finally, findings indicate that purpose-built bicycle-only facilities are perceived by cyclists as safer environments for riding a bike.

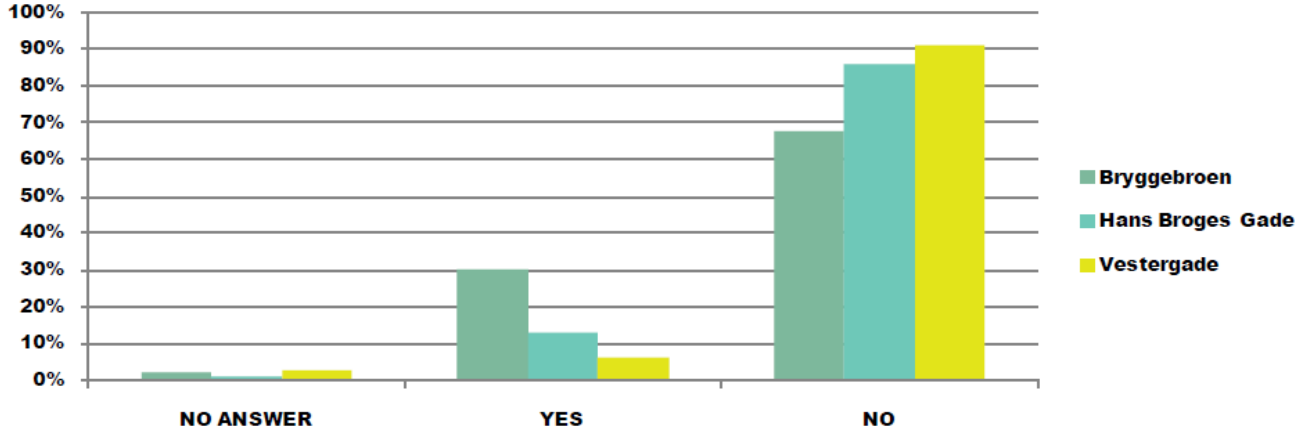

Figure 9: Distribution of the respondents in accordance to biking more often after the opening of the infrastructure.

Design qualities influencing respondents' choice of biking more often

Respondents were asked what design aspects of a bike infrastructure motivates them to ride their bikes more often. The largest portion of the respondents stated that faster connections (43%) and faster bike lanes (21%) are the design aspects that primarily motivate them to ride a bike more often. Regardless the infrastructure typology, fast connectivity appears as a critical factor when respondents are asked about motivation to ride a bike. The results highlight that bike infrastructures designed to provide more direct and faster connections motivate cyclists and enhance cycling. It is relevant to mention that these are findings from the Danish urban context. Moreover, the visual experience and safety also appears as relevant factors motivating individuals to ride more often a bike.

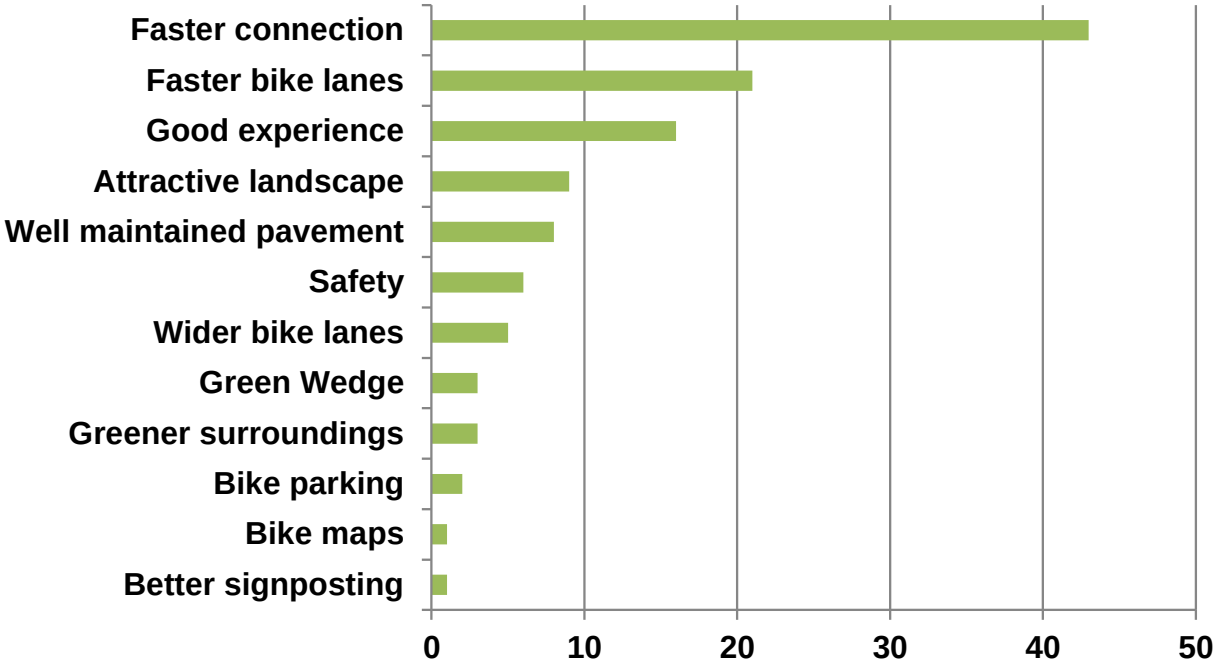

Figure 10: Distribution of the respondents in accordance to what design quality most motivates them to ride a bike more often.

These results are interesting, when compared to the notions of 'transportation rationales' coined by Næss & Jensen (2005). Accordingly, there are (at least) 6 fundamental categories of rationales that may serve to explore why people chose different modes or routes. The person on the move may choose mode of transport or route according to the shortest distance or travel time (instrumental rationale), perceived safety (safety rationale), most beautiful route or scenery (aesthetic rationale), how one usually do (routine rationale), what is most pleasant or comfortable (comfort rationale), or how one feels the atmosphere (affective rationale). These are abstract and analytical categories and will in practice often be found in a complex agglomeration. In this research, we found the instrumental rationale and the affective rationale being the two most central (see figure 10). The safety rationale is also present but perhaps with less imprint than one would have expected given the general discourse of cyclists as vulnerable in the traffic.

CONCLUSION

The study aimed to give an overview with regards to what design characteristics would be relevant to individual's decision to ride a bike. The analysis of the collected data indicated possible relevant design factors and also relations between socio-demographic factors and how design characteristics influence the individual decision to ride a bike. The findings highlight the relevance of fast connectivity for cyclists. The results suggest that fast connectivity is the most critical dimension of a design solution that must be taken into consideration by architects, planners and engineers.

Based on the comparison between the three case studies, the shared-used space seems to present more challenges for the cyclists who need to ride their bikes and, at the same time, negotiate their space with pedestrians. Shared-use spaces are not common in Denmark, but they can be an alternative way to create more lively urban spaces enhancing a variety of experiences. However, this may depend on a longer process of appropriation within a traffic culture that has been extremely regulated over many decades. The open and dynamic situations of shared spaces may be seen as out of touch with the Danish experience of detailed and highly regulated traffic design. For research on the differences in cycling culture see Furnness (2010), Jensen (2007), Mikkelsen, Smith & Jensen (2011). Further research must document if the Danish context is less open to appropriating the shared space planning doctrine than other nations.

The three studied typologies have both advantages and disadvantages. When deciding to implement or improve a bike infrastructure, the particular qualities and potentials of each typology should be analysed in order to decide what kind of bike infrastructure would be appropriate to be implemented. In the three case studies, the majority of respondents answered that they ride a bike in their respectively infrastructures with the main purpose to go to or from work. Consequently, different typologies or a conjugation of typologies could be efficiently used for commuting.

The findings highlight important factors as such the relevance of fast connectivity, the visual experience and safety for cyclists. Therefore, these three qualities are strategic dimensions of a design solution that must be taken into consideration by architects, planners and engineers. Bridging research and policy, the findings of this research project can also support bike friendly design and planning, and cyclist advocacy.

This study draws a number of conclusions. In doing so it is acknowledged that there are not available studies in regards to the relation between design characteristics and motivation to ride a bike in Denmark. Therefore, the conclusions are provisional, pending further research.

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