Exploring the bicycle planning culture and implementation challenges: case studies of Hamburg and Wuhan

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Abstract

Many cities are suffering from problems caused by extensive car use. Cycling, as a mode of transport, can be helpful to reduce emissions, improve public health, and increase traffic efficiency. However, transport planning in many cities has been focused on motorized transport and overlooked cyclists. To shape a supportive urban environment for cyclists, a number of important questions with regard to bicycle planning are not yet fully understood, for instance, the relationship between the built environment and cycling, the barriers to implementing pro-cycling policies, and the bicycling planning culture in growing cities.

This thesis is structured around four objectives. The first objective is to investigate the relationship between the objectively measured built environment and active transportation (walking and cycling for transport) among adults. A systematic literature review of journal articles from four databases was conducted. The systematic literature search identified 51 articles published between 2005 and 2017. From the 51 articles, 12 built environment factors were extracted. The results show that most studies examined factors related to walkability and accessibility. Street connectivity shows a convincing positive relationship with both walking and cycling for transport. However, neighborhood aesthetics and access to destinations show inconsistent relationships. In addition, choosing suitable geographic units and measurement of active transportation is necessary to reduce the mismatch in the relationships.

The second objective is to identify barriers to implementing pro-cycling policies. While many studies have recommended policy interventions to promote cycling, not enough research has focused on the barriers to implementing pro-cycling policies. This study took an in-depth look at Hamburg, which started a major cycling promotion in 2008 with a range of interventions. According to expert interviews and literature surveys, the results show that the major barriers are physical (lack of enough physical space), political and institutional (lack of political support and the evaluation of travel behavior), and social and cultural (people's reluctance to give up on-street car parking space). Suggestions for overcoming the barriers are proposed.

The third objective is to explore the bicycle planning culture in a growing city. A case study was conducted in Wuhan, China. Data were collected through semi-structured expert interviews and a questionnaire survey. The exploration of bicycle planning culture was guided by the culturized planning model. The results indicate that bicycle planning practices in Wuhan are more often based on planners' individual judgments with informal rules, which sometimes do not assign cycling a legitimate role. While the principles are targeting a cycling-friendly street design, the actual improvement of the cycling infrastructure is selective and fragmented. Planners have positive perceptions of cycling but doubts about bicycle commuting. Planners are inclined to consider bicycle transport as a complement to public transport.

The fourth objective is to compare bicycle planning in different contexts. Bicycle planning culture in Hamburg and Wuhan are compared by using the culturized planning model. The results indicate that although cycling is gaining increasing attention in both cities, the two cities show significant differences in the level of professionalism of bicycle planning. Hamburg has a more systematic bicycle plan, a more detailed implementation strategy, and stronger political support. Cycling is already an important part of the transport system of Hamburg; however, it plays a marginal role in that of Wuhan, where there are more ambivalent and negative attitudes towards cycling.

In general, this thesis contributes to a better understanding of bicycle planning with regard to different aspects, including the built environment, policy implementation and planning culture. To further investigate the relationship between the built environment and cycling for transport, more longitudinal studies and more studies in different contexts are needed. For an effective policy implementation, more research is necessary to explore how to gain stronger political support and how to create space for cycling infrastructure in space-scarce cities. Also, the role of cycling for transport in large growing cities should be further explored.

Keywords: cycling; bicycle planning; planning culture; pro-cycling policy

Zusammenfassung

Viele Städte sind mit Problemen konfrontiert, die durch eine intensive Autonutzung verursacht werden. Radfahren als Beförderungsart kann hilfreich sein, um Emissionen zu reduzieren, die öffentliche Gesundheit zu verbessern und die Verkehrseffizienz zu steigern. In vielen Städten hat sich die Verkehrsplanung jedoch auf den motorisierten Verkehr konzentriert und die RadfahrerInnen übersehen. Um eine unterstützende städtische Umgebung für RadfahrerInnen zu schaffen, sind eine Reihe wichtiger Fragen im Kontext der Radverkehrsplanung nach wie vor nicht vollständig beantwortet, z.B. hinsichtlich des Zusammenhangs zwischen baulicher Umwelt und Radfahren, den Hindernissen für die Umsetzung fahrradfreundlicher Politiken sowie der Radverkehrsplanung in wachsenden Städten.

Mit dieser Arbeit sollen vier Ziele erreicht werden. Das erste Ziel ist, den Zusammenhang zwischen der nach objektiven Kriterien analysierten baulichen Umwelt und dem aktiven Verkehr (Fuß- und Radverkehr) bei Erwachsenen zu untersuchen. Dazu wurde eine systematische Literaturrecherche von Zeitschriftenartikeln aus vier Datenbanken durchgeführt. Mit der systematischen Literaturrecherche konnten 51 Artikel identifiziert werden, die zwischen 2005 und 2017 veröffentlicht wurden. Aus diesen 51 Artikeln wurden wiederum zwölf Faktoren für die gebaute Umwelt bestimmt. Die Ergebnisse zeigen, dass die meisten Studien Faktoren hinsichtlich Fußgängerfreundlichkeit und Zugänglichkeit untersuchten. Die Verbundenheit der Straßen zeigt eine eindeutig positive Beziehung sowohl zum Fuß- als auch zum Radverkehr. Hinsichtlich der Ästhetik des Quartiers sowie des Zugangs zu den jeweiligen Zielen zeigen sich jedoch uneinheitliche Zusammenhänge. Darüber hinaus sind die Wahl geeigneter geografischer Einheiten und die Messung des aktiven Verkehrs notwendig, um Diskrepanzen in den Beziehungen zu reduzieren.

Das zweite Ziel besteht darin, Hindernisse für die Umsetzung einer radfahrfreundlichen Politik zu identifizieren. Während viele Studien politische Maßnahmen zur Förderung des Radfahrens empfohlen haben, hat sich die Forschung nicht ausreichend auf die Hindernisse bei der Umsetzung fahrradfreundlicher Strategien konzentriert. Diese Studie beschäftigte sich eingehend mit Hamburg, das 2008 mit einer umfangreichen Förderung des Radverkehrs begann und dazu eine Reihe unterschiedlicher Maßnahmen umsetzte. Basierend auf Experteninterviews und Literaturrecherchen zeigen die Ergebnisse, dass die größten Barrieren hinsichtlich physischer (Mangel an genügend physischem Raum), politischer und institutioneller (Mangel an politischer Unterstützung und Evaluierungen des Reiseverhaltens) sowie sozialer und kultureller (Zurückhaltung der Menschen, auf Straßenparkplätze zu verzichten) Aspekte bestehen. Es werden Vorschläge zur Überwindung dieser Hindernisse unterbreitet.

Das dritte Ziel ist die Erforschung der Radverkehrsplanungskultur in einer wachsenden Stadt. Eine Fallstudie wurde in Wuhan, China, durchgeführt. Die Daten wurden durch semi-strukturierte Experteninterviews erhoben und durch eine quantitative Datenerhebung. Die

Erforschung der Radverkehrsplanungskultur wurde durch ein analytisches Modell zur Planungskultur geleitet. Die Ergebnisse belegen, dass die Radverkehrsplanungspraxis in Wuhan überwiegend auf individuellen Beurteilungen der PlanerInnen mit informellen Regeln basiert, die dem Radfahren normalerweise keine legitime Rolle zuweisen. Während die Grundprinzipien zwar auf eine fahrradfreundliche Straßengestaltung abzielen, ist die tatsächliche Verbesserung der Radverkehrsinfrastruktur punktuell und bruchstückhaft. PlanerInnen nehmen Radfahren in positiver Weise wahr, haben jedoch Vorbehalte gegenüber dem Pendeln mit dem Fahrrad. PlanerInnen betrachten Radverkehr als Ergänzung zum Öffentlichen Nahverkehr.

Das vierte Ziel ist, die Radverkehrsplanung in verschiedenen Kontexten zu vergleichen. Die Radverkehrsplanungskultur in Hamburg und Wuhan wurde anhand des analytischen Modells zu Planungskultur verglichen. Die Ergebnisse deuten darauf hin, dass obwohl Radfahren in beiden Städten zunehmend an Bedeutung gewinnt, erhebliche Unterschiede im Grad der Professionalität der Radverkehrsplanung bestehen. Hamburg hat einen systematischeren Radverkehrsplan, eine detailliertere Umsetzungsstrategie und eine stärkere politische Unterstützung. Das Radfahren ist bereits ein wichtiger Teil des Hamburger Verkehrssystems, spielt aber im Verkehrssystem von Wuhan nur eine marginale Rolle. In Wuhan gibt es stattdessen mehr ambivalente und negative Einstellungen zum Radfahren.

Im Allgemeinen trägt diese Arbeit zu einem besseren Verständnis der Radverkehrsplanung in Bezug auf verschiedene Aspekte bei, einschließlich der baulichen Umwelt, der politischen Umsetzung und der Planungskultur. Um den Zusammenhang zwischen der baulichen Umwelt und dem Radverkehr weiter zu untersuchen, sind weitere Längsschnittstudien sowie weitere Studien in verschiedenen Kontexten erforderlich. Für eine effektivere Politikumsetzung sind weitere Forschungsarbeiten notwendig, um zu analysieren, wie eine stärkere politische Unterstützung erhalten und wie in hochverdichteten Städten Raum für Radverkehrsinfrastrukturen geschaffen werden kann. Auch die Rolle des Radverkehrs in großen, wachsenden Städten sollte weiter untersucht werden.

Schlagwörter: Radfahren; Radverkehrsplanung; Planungskultur; Radverkehrspolitik

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List of Abbreviations

AT	active transportation
ADFC	Allgemeine Deutsche Fahrrad-Club e. V.
B+R	bike-and-ride
DBS	Dockless bike-sharing
EPHPP	Effective Public Health Practice Project Quality Assessment Tool
GIS	geographical information system
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses

1. Introduction

1.1 Background

In many countries, the transport sector is responsible for a considerable share of energy consumption and greenhouse gas emissions (Chai, Yang, Wang, & Lai, 2016; European Commission, 2016b). In Europe, while many sectors (e.g. agriculture and industry) have decreased their emissions significantly since 1990, transport emissions have only begun to decrease since 2007 due to the economic crises, and they still remain above the 1990 level (European Commission, 2016a). Within the transport sector, the majority of greenhouse gas emissions have been produced by road transport (72.8% in 2014)—more than those produced by navigation, civil aviation, railways, and other modes combined (European Commission, 2016a). In China, from 1990 to 2014, the total energy consumption from the transport sector increased six times (Han, Yu, Tang, Liao, & Wei, 2017). With extensive car use, many cities are suffering from air pollution, noise, traffic congestion, and accidents (Gössling, Schröder, Späth, & Freytag, 2016; He & Qiu, 2016). The significant carbon emissions around the world not only exacerbate climate change, but also do harm to public health (S. Yang & He, 2016). Therefore, there is an urgent need to reduce dependence on cars in order to shape a sustainable road transport system.

To reduce dependence on cars, cycling is gaining increasing attention as it can benefit the transport system and improve quality of life (Handy, van Wee, & Kroesen, 2014). Cycling is an efficient and low-cost mode of transport for short-distance travel without producing air and noise pollution (Handy et al., 2014; Koglin & Rye, 2014; Pucher, Dill, & Handy, 2010). Cycling, particularly bike-sharing schemes, helps mitigate traffic congestion and broadens the service area of public transport, thereby increasing the overall transport efficiency (Shi, Si, Wu, Su, & Lan, 2018; M. Wang & Zhou, 2017; J. Zhao, Deng, & Song, 2014). Studies using cost-benefit analysis have identified the significant value of installing cycling infrastructure (Brey et al., 2017; Standen, Greaves, Collins, Crane, & Rissel, 2018). Also, researchers have found that increasing the size of the bicycle network helps reduce greenhouse gas emissions (Zahabi, Chang, Miranda-Moreno, & Patterson, 2016).

In addition to being an environmentally friendly mode of transport, it is widely acknowledged that cycling also benefits physical health (de Hartog, Boogaard, Nijland, & Hoek, 2010; Götschi, Garrard, & Giles-Corti, 2016; Oja, Vuori, & Paronen, 1998; Schauder & Foley, 2015). Physical inactivity has been shown to be a key factor leading to mortality and various diseases, including obesity, diabetes, and cardiovascular disease (World Health Organization, 2017). Cycling for transport is a feasible way to improve the level of daily physical activity and reduce a sedentary lifestyle (de Hartog et al., 2010; Schauder & Foley, 2015). Sufficient physical activity can also improve mental health and one's mood (Deffner, Hefter, Rudolph, & Ziel, 2012). Studies have found that commuting by walking or cycling is more satisfying than driving or taking public transport (Olsson, Gärling, Ettema, Friman, & Fujii, 2013).

Cycling can also contribute to social inclusion and connection by improving accessibility and mobility (Götschi et al., 2016; Smith, 2016). With cycling, people who have no access to a car or do not want to drive a car can have an equal chance of traveling. This can particularly benefit individuals who have a low income (Buehler & Pucher, 2012). Also, neighborhoods dominated by cycling and walking are more pleasant to live in. A study in the UK found that residents who live in streets with a higher motor traffic volume tend to have fewer local friends, indicating that active travel contributes to more street-based social life (Hart & Parkhurst, 2011).

Despite the various benefits of cycling, modern transport planning has been focused on motorized traffic and overlooked cyclists and pedestrians for a long time (Koglin & Rye, 2014; Pucher & Buehler, 2017). In many cities, there is a mismatch between motorized infrastructure and nonmotorized infrastructure in that most road spaces are for motor traffic (Gössling et al., 2016). In such auto-oriented cities, cyclists are vulnerable road users that are exposed to pollutants, take higher traffic risks and make more detours (Gössling, 2016; Koglin & Rye, 2014; Mullen, Tight, Whiteing, & Jopson, 2014). To increase safety and accessibility for nonmotorists, it is necessary to plan more for cycling and create more equitable urban space (Koglin, 2011).

1.2 State of knowledge

1.2.1 Active transportation and built environment

Cycling for transport is frequently planned and studied as one type of active transportation (AT). AT is any nonmotorized travel based on human power, and mostly refers to walking and cycling for transport (utilitarian purposes) (Litman, 2003; Sallis, Frank, Saelens, & Kraft, 2004). In some countries (e.g., China), transport plans for cycling are normally made together with walking. In other words, there is no separate planning system for cycling in many cities. Therefore, it is necessary to first consider cycling as a means of transport in the context of AT, then to zoom in to cycling for transport specifically in the following state of knowledge and research.

In recent years, AT has aroused great interest in both the urban planning and public health fields (Berglund, Lytsy, & Westerling, 2016; Haybatollahi, Czepkiewicz, Laatikainen, & Kyttä, 2015; Rabl & de Nazelle, 2012). Shifting from car use to AT can be a promising way to reduce the health risks of physical inactivity, as well as to reduce air pollution, noise and traffic congestion (Berglund et al., 2016; Rabl & de Nazelle, 2012). To achieve the modal shift, a supportive built environment is crucial (Marshall, Piatkowski, & Garrick, 2014; World Health Organization, 2017).

Exploring the relationship between AT and the built environment helps provide urban design guidance to assist planners (Ewing & Cervero, 2010; Tracy, Su, Sadek, & Wang, 2011). AT can be measured in different ways, for example trip distance, frequency, and duration. These can be recorded either by self-reported travel surveys and diaries, or by GPS devices. The built environment is frequently measured with five “D” variables: density, diversity, design, distance to transit, and destination accessibility (see Table 1.1 for detailed explanations) (Cervero & Kockelman, 1997; Cervero, Sarmiento, Jacoby, Gomez, & Neiman, 2009; Ewing & Cervero, 2010; Ewing, Hajrasouliha, Neckerman, Purciel-Hill, & Greene, 2016; Haybatollahi et al., 2015; Lee & Moudon, 2006b; Tracy et al., 2011).

Table 1.1. Five "D" variables for characterizing the built environment

	Example of measurements	**Example of assumptions**
Density	Population density (dwelling units per hectare)	Trips in high-density areas are expected to be shorter
Diversity	Entropy index of land use mix	Mixed land use encourages short-distance commuting and trip chains
Design	Street connectivity (connectivity index); street density (road km/land area km^2)	Dense and well-connected streets encourage walking and cycling and reduce detours
Distance to transit	The shortest network distance between one's home and the closest public transport station; the number of public transport stations within the buffer area	Proximity to transit encourages using active transportation for access to and egress from the public transport services
Destination accessibility	The number of destinations (e.g., shops, restaurants, schools, workplaces, churches) within the buffer area around one's home address	Proximity to services and shops encourages short-distance travel by active transportation

Source: Cervero et al. (2009); Tracy et al. (2011)

The built environment can be perceived (e.g., questionnaire) and objectively measured (e.g., geographical information system (GIS), audit tools). Some built environment factors are frequently found to have a positive relationship with AT, for example, land use diversity, street connectivity, and destination accessibility (Christiansen et al., 2016; Ewing & Cervero, 2010; C. Zhao, Nielsen, Olafsson, Carstensen, & Meng, 2018).

1.2.2 Determinants of cycling for transport

It is widely recognized that people's travel mode choice is affected by various factors (Deffner & Hefter, 2015; Fernández-Heredia, Monzón, & Jara-Díaz, 2014; Heinen, van Wee, & Maat, 2010; Klinger, Kenworthy, & Lanzendorf, 2013; Pucher et al., 2010). Travel behavior sometimes is not a rational choice but a lifestyle and part of mobility routines (Deffner, Hefter, Rudolph, & Ziel, 2012). To get a full picture of factors influencing urban mobility, researchers have developed a mobility culture framework that integrates both subjective and objective dimensions, namely political decisions, urban planning, the historically produced space, the socio-economic situation, lifestyles milieus, and communication (Figure 1.1) (Deffner et al., 2006; Deffner & Hefter, 2015; Klinger et al., 2013).

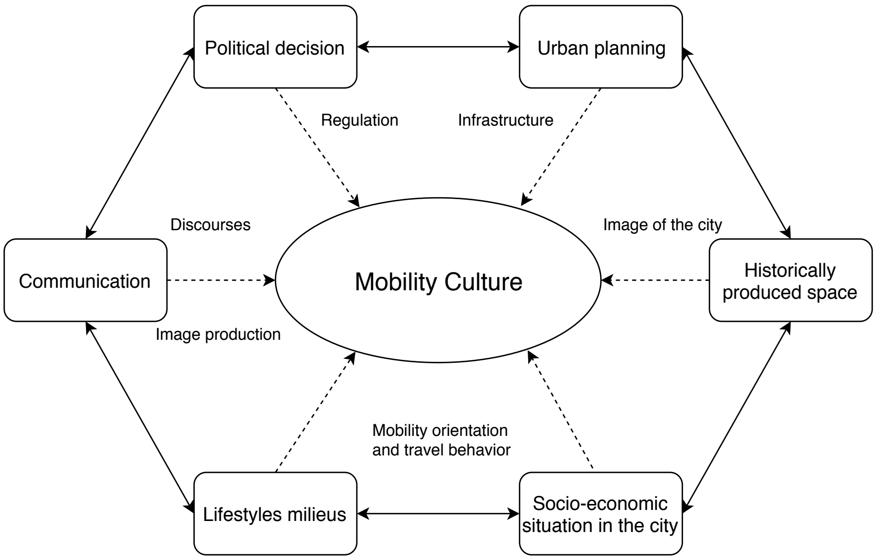

Figure 1.1. The concept of urban mobility culture.

Source: Deffner et al., (2006); Klinger et al., (2013).

The dimension of political decision influences mobility culture by providing the general policy context and regulations. Urban planning decides the transport infrastructure supply, which influence travel behavior by its quality and quantity. Historical produced space reflects a city's fundamental geographic context and infrastructure condition (Kuhnimhof & Wulfhorst, 2013). Historical produced space and urban planning together shape urban form characteristics (e.g., residential density). Socio-economic situation is frequently referring to age, income, and employment (Klinger et al., 2013). For instance, people with higher incomes have higher access to private cars (Dieleman, Dijst, & Burghouwt, 2002). Lifestyles milieus are related to people's perceptions and attitudes to different travel modes (Klinger et al., 2013). Communication reflects discourses, public debates, cooperation, marketing and public participation mechanisms (Kuhnimhof & Wulfhorst, 2013). These six dimensions are interrelated, together forming the mobility culture of a city.

Focusing on cycling for transport, Rietveld and Daniel (2004) proposed that factors affecting bicycle use include individual features, socio-cultural conditions, generalized costs of cycling and other modes of transport, local authority initiatives, and policy influence. Similarly, Fernández-Heredia et al. (2014) grouped the influential factors as general *socio-demographic characteristics* (age, gender, income, etc.), *attitudes towards cycling, cycling context conditions, cyclist's choice factors* (trip purpose, weather, bicycle infrastructure, etc.), *general transport costs* and *cycling mobility costs* (Figure 1.2).

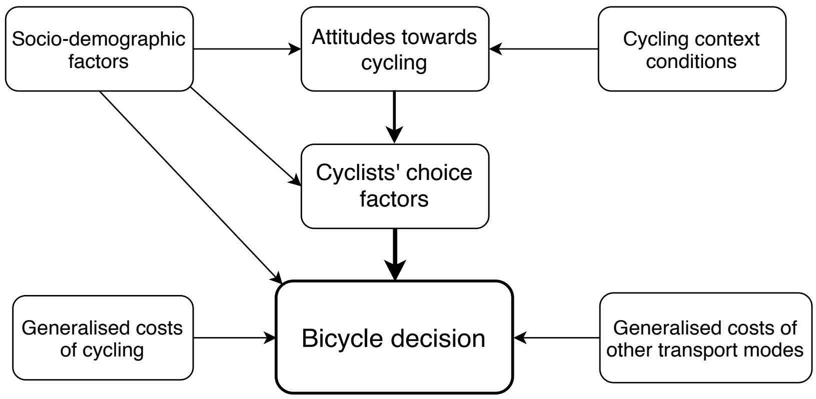

Figure 1.2. Determinants of cycling.

Source: Fernández-Heredia et al., (2014); Rietveld & Daniel, (2004).

- Socio-demographic factors

With regard to general socio-demographic factors, age might be associated with people's physical fitness (Rantakokko, Mänty, & Rantanen, 2013; Rietveld & Daniel, 2004), and gender differences may play a role when cycling at night (Rietveld & Daniel, 2004). Heesch, Giles-Corti and Turrell (2014) found that having less access to private cars and part-time employment were related to higher levels of cycling for transport. However, in cities with a higher cycling level, socio-demographic factors might be less decisive. Pucher and Buehler (2008) found that in the Netherlands, Denmark, and Germany, cycling was more popular, and there were fewer differences in cycling use among different age, gender and income groups than in America and the UK. Similarly, in a comparative study between Adelaide and Ghent, Owen et al. (2010) found that the cycling level was higher in Ghent, and there were fewer differences in bicycle use among different age groups in Ghent.

- Cyclists' attitudes and perceptions.

Many studies have emphasized the influence of cyclists' attitudes and perceptions. Perceived traffic risk was found to be negatively associated with the decision to cycle, especially among less frequent cyclists (Sanders, 2015). Fernández-Heredia et al. (2014) found that perceptions related to convenience (flexible, efficient) and exogenous restrictions (danger, vandalism, facilities) were the most influential factors for cyclists. Moreover, perceived barriers of physical discomfort and the impracticality of cycling were found to have a negative association (Titze et al., 2008). In different contexts, some people treat cycling as a mainstream and environmentally friendly mode choice, some treat it as a tool for recreation and fitness, and some other people regard it as a subcultural mode and the poor people's choice (Aldred & Jungnickel, 2014; Lanzendorf & Busch-Geertsema, 2014; Rietveld & Daniel, 2004).

- Cycling context conditions

However, cyclists' attitudes and perceptions can be influenced by cycling context conditions. Cycling context conditions include cycling culture and policies, mobility governance, and motorized traffic restrictions (Fernández-Heredia et al., 2014). Implementing pro-cycling policies and providing better cycling infrastructure help mitigate these perceived barriers and increase the public image of cycling (de Sousa, Sanches, & Ferreira, 2014; Pucher & Buehler, 2008; Raser et al., 2018).

- Cyclist's choice factors

Regarding cyclist's choice factors, built environment factors play critical roles. Some built environment factors are found to have a positive relationship, including the presence of cycle lanes or tracks (Braun et al., 2016; L. Ma & Dill, 2015; Mertens et al., 2017; Zahabi et al., 2016; P. Zhao, 2014), and street connectivity (Christiansen et al., 2016; Dill & Voros, 2007; Fan, Wen, & Kowaleski-Jones, 2014; Rybarczyk & Wu, 2014; Zahabi et al., 2016; P. Zhao, 2014). Slopes were found to have a negative association (Cervero et al., 2009). Weather could also affect cycling for transport. For example, extremely high or low temperatures, heavy rain and snow might lead to uncomfortable feelings and the risk of accidents, and therefore discourage cycling (Pucher & Buehler, 2006).

- Costs of cycling and other modes of transport

The costs of general transport and cycling also have an impact on people's choice of cycling. For example, studies found that the increasing use of cycling during 1970s–1990s in Germany had a close relationship with the high price of fuel and urban congestion (Maddox, 2001). Cycling became popular partly because of its relatively cheap cost during this period of severe economic deprivation (Sheldrick, Evans, & Schliwa, 2017). Nowadays, with the popularization of bike-sharing systems, bicycles are becoming more and more accessible with a fee that is affordable for almost everyone. A recent study in China found that an increasing number of walkers have turned to using the shared bikes (Y. Li, Xing, Wang, Liang, & Wang, 2018).

1.2.3 Strategies to promote cycling for transport and best practices

Strategies to promote cycling for transport include infrastructure provision, community design, legal intervention, and programs (Table 1.2) (Forsyth & Krizek, 2010; Pucher et al., 2010; Scheepers et al., 2014). Infrastructure provision and community design are also called "hard measures," which focus on structural change. Policy and legal intervention, communication, and marketing can be called "soft measures," which focus on psychosocial aspects to achieve modal shifts (Eriksson, Garvill, & Nordlund, 2008; Gössling, 2013; Krizek, Forsyth, & Baum, 2009).

Table 1.2. Measures to promote cycling for transport

Measure	**Examples of measures**
Infrastructure provision	Provide cycle lanes and tracks, intersection treatments, and parking facilities
Community design	Mixed land use, well-connected streets, increase the proximity to services
Legal intervention	Speed limits for vehicles, increase car parking fees
Program (education,	Cycling training, education on traffic rules, communication

communication, and marketing)	campaigns, bike to school/work programs, bike rental schemes, and bike–and–ride (B+R) services

Source: Krizek et al. (2009); Pucher et al. (2010)

Providing cycling infrastructure is considered of high efficacy in promoting cycling (Forsyth & Krizek, 2010; Krizek et al., 2009; Marqués, Hernández-Herrador, Calvo-Salazar, & García-Cebrián, 2015). Improving cycling infrastructure is the main task for pro-cycling policies in many cities. Different cycling infrastructure includes cycle lanes (separated from motor traffic by painted lines) (Figure 1.3), cycle tracks and paths (physically separated from motor traffic) (Figure 1.4), different types of parking facilities (Figure 1.5), cycling-specific traffic signs and lighting, and intersection treatments (Buehler & Dill, 2016; Deffner et al., 2012; Harms, Bertolini, & Brömmelstroet, 2016). Other than cycle lanes, tracks, and paths, German cities are innovative in establishing bicycle priority streets (Figure 1.6). For example, on a cycle street (Fahrradstrasse), cyclists have priority on the entire street with minimal car traffic (Buehler, Pucher, Gerike, & Götschi, 2017).

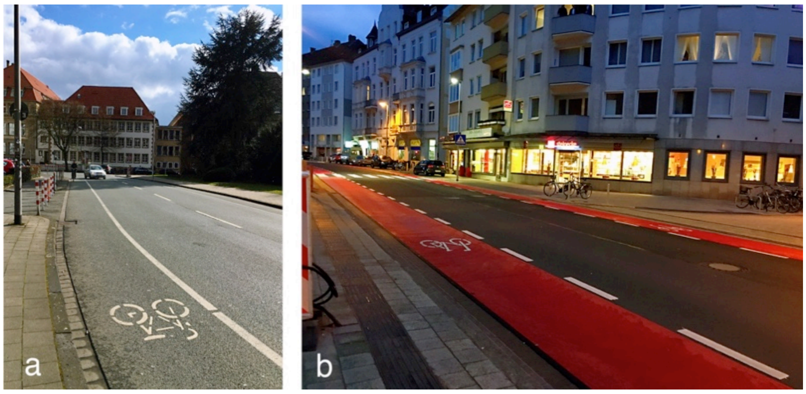

Figure 1.3. Cycle lanes.

(a): a mandatory cycle lane with a continuous line marking. Motor traffic is not allowed to drive in this area; (b): an advisory cycle lane with a dashed line marking (when space is lacking). Motor traffic is advised not to use this area, but it is allowed to use it. Colored surfaces can increase visibility (Deffner et al., 2012) (photos by author, a: Muenster; b: Hannover).

Figure 1.4. Cycle tracks.

(a): cycle track separated from motor traffic with a fence; (b) and (c): cycle tracks located alongside the sidewalks. Cycle tracks protect the safety of cyclists by being physically separated from motor traffic. But cyclists can be less visible to drivers at intersections when drivers' view is blocked by, for example,

(a) a fence or (b) car parking (Deffner et al., 2012) (photos by author, a: Wuhan; b: Hamburg; c: Hannover).

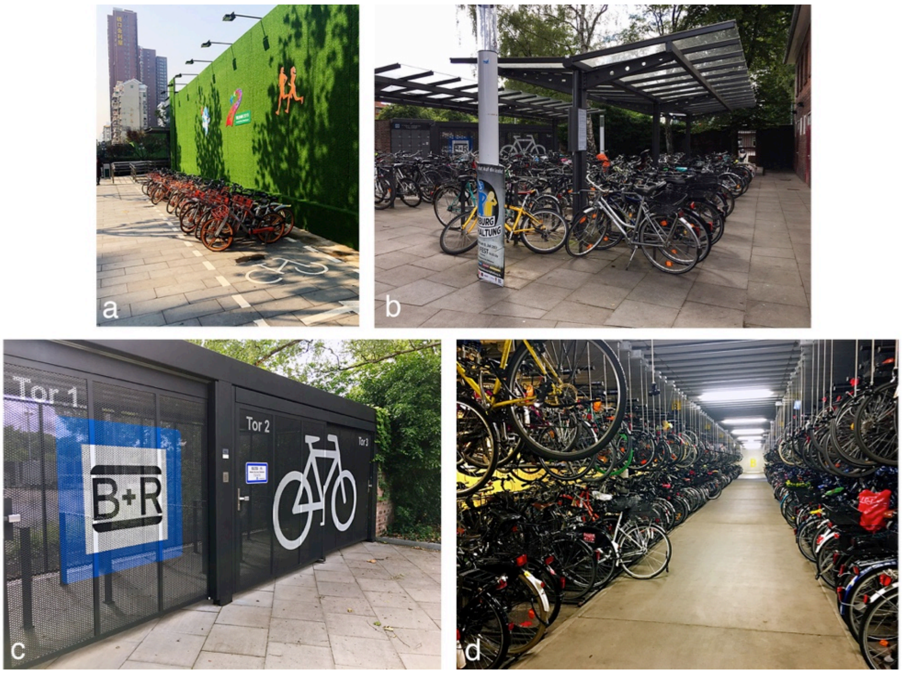

Figure 1.5. Bike parking facilities.

(a): parking area defined by painted lines; (b): parking facility with roofs; (c): rentable bike storage boxes with locks, located close to public transport stations for bike-and-ride services; (d): a bike station near the central station of Muenster, with over 3,000 parking spaces and bike rental and repair services (photos by author, a: Wuhan; b: Hamburg; c: Hamburg; d: Muenster).

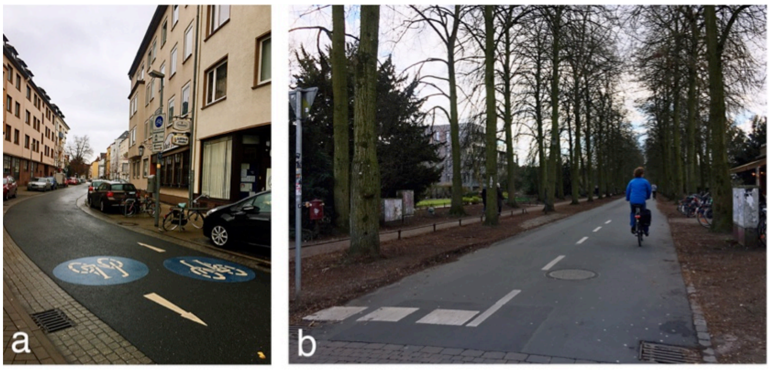

Figure 1.6. Bicycle priority streets.

(a): a cycle street (Fahrradstrasse); (b): promenade, car-free beltway for cyclists and pedestrians (photos by author, a: Hannover; b: Muenster).

Importantly, many studies suggest that a highly effective way to promote cycling is to combine different measures (Forsyth & Krizek, 2010; Gössling, 2013; Lanzendorf & Busch-Geertsema, 2014; Pucher & Buehler, 2008; Pucher et al., 2010; Sagaris, 2015; Savan, Cohlmeyer, & Ledsham, 2017): for example, a combination of pull (“carrots”) and push (“sticks”) measures (Harms et al., 2016; Piatkowski, Marshall, & Krizek, 2019). Pull measures can make cycling more attractive by improving cycling infrastructure and services. Push measures try to make car use more expensive and less convenient (Harms et al., 2016). Measures with different focuses can complement each other (Pucher & Buehler, 2008).

Several cities in Denmark, the Netherlands, and Germany have long been considered best practices in being cycling-friendly. The frequently noted cities include *Copenhagen, Amsterdam, and Muenster* (Pucher & Buehler, 2008). The modal share of cycling accounted for 28% in Copenhagen in 2017 (City of Copenhagen, 2018), 27% in Amsterdam in 2016 (Harms & Maarten, 2018), and 39% in Muenster in 2013 (Stadt Münster, 2017). Cycling has become the fastest and most convenient travel mode for many citizens in these cities. All these three cities have expended great efforts in improving cycling infrastructure systematically, and the accident rate of cyclists has been decreasing (Pucher et al., 2010). With strong political support and a professionalized bicycle planning environment, cycling has an important position in their transport plans (Marije de Boer & Caprotti, 2017; C. Zhao, Carstensen, Nielsen, & Olafsson, 2018).

In recent years, a surge in cycling has occurred in many cities, including *Bogota, Seville, and Portland*. In Bogota, Colombia, the share of cycling increased from 0.58% in 1996 to 4.4% in 2003 (Cervero et al., 2009). In 2017, 6.3% of people cycled to work (Charry, 2019). With a huge investment in cycling infrastructure and experience from the Netherlands, Bogota has constructed an extensive bikeway network. The infrastructure improvement is also combined with many travel programs (e.g., “Ciclovias”) (Pucher et al., 2010). Seville (Spain) is another city with a rapid increase in cycle use. Starting from 2006, Seville constructed a cycling network in a short period of time. The city constructed a basic cycle network of 77 km from 2006 to 2007, followed by a complementary network up to 120 km from 2008 to 2010 (Marqués et al., 2015). The modal share of cycling of all mechanical trips increased from 1.1% in 1990 to 8.9% in 2011 (Marqués, Hernández-Herrador, & Calvo-Salazar, 2014). The promotion of cycling in Seville also includes developing a public bike-sharing scheme and B+R programs (Marqués et al., 2015). Portland is one of the cycling-friendly cities in the USA (Buehler & Dill, 2016). The length of bikeways increased from 79 miles in 1991 to 274 miles in 2008, and the modal share of commuting trips by bike increased from 1.1% in 1990 to 6.0% in 2008 (Pucher et al., 2010). In summary, the evidence from these cities proved that it is possible to promote cycling in a context without a cycling culture (Pucher & Buehler, 2017).

1.2.4 Bicycle planning and cycling trends in Germany and China

- Bicycle planning and cycling trends in Germany

Facing the harmful impacts of increasing car use after the Second Word War, German cities started to facilitate cycling, as well as walking and public transport, in the mid-1970s (Pucher & Buehler, 2008). The first German national cycling plan was released in 2002, which provided recommendations on methods and implementation strategies to promote cycling between 2002 and 2012 (Federal Ministry of Transport Building and Housing, 2002). In 2013, the *National Cycling Plan 2020* was adopted. The National Cycling Plan 2020 is aimed at improving the regulatory framework of cycling, promoting cycling as an element of integrated transport and mobility policy, implementing the vision of “cycling as a system” and contributing to tackling social challenges (Federal Ministry of Transport Building and Urban Development, 2012). The *National Cycling Plan 2020* identified nine action areas for systematically promoting cycling use, including planning and developing a cycling strategy, infrastructure, road safety, communications, cycle tourism, electric mobility, linkage with other means of transport, mobility and road safety education, and the creation and safeguarding of qualities. There are also interconnections among different areas (Federal Ministry of Transport Building and Urban Development, 2012).

In the last two decades, the use of cycles in Germany has been increasing slowly (Figure 1.7). The national average modal share of cycling was 11% in 2017 (Follmer, 2018). About 80% of all households have at least one bicycle and 25% have three or more bicycles (Federal Ministry of Transport Building and Urban Development, 2012). The ECF (European Cyclists' Federation) Bicycling Barometer assessed the state of cycling in European countries based on five aspects: cycling usage, road safety, cycling tourism, state of the market and recognized cycling advocacy organizations (ECF, 2015). Germany ranked fifth in 2015 among 28 countries, with Denmark and the Netherlands being the top two (ECF, 2015).

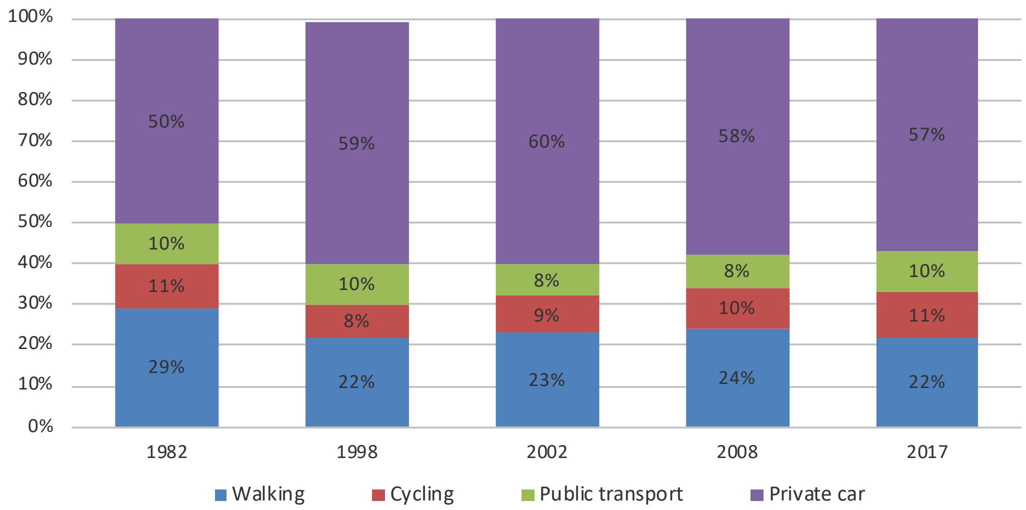

Figure 1.7. The modal split of Germany from 1982 to 2017.

Source: Follmer, (2018); Infas/DLR, (2010).

In different cities in Germany, there are big differences in cycle use (Federal Ministry of Transport Building and Urban Development, 2012). In some towns and cities, the modal share of cycling is above 30% (e.g., Muenster, Bocholt, Oldenburg, Greifswald); but in some other cities, the modal share of cycling is less than 5% (e.g., Wiesbaden) (Federal Ministry of Transport Building and Urban Development, 2012; Goetzke & Rave, 2011). Cycling promotion first boomed in small and medium-sized cities, and it wasn't until recent years that big cities also began to put effort into cycling promotion (Lanzendorf & Busch-Geertsema, 2014). To support the local authorities properly, the *National Cycling Plan 2020* gave priorities to municipalities with different starting points. The plan adopted the model that was developed by the ECF, in which the development of cycling was divided into three categories ("starter," that with a modal share of cycling of less than 10%; "climber," that with between 10% and 25%; and "champion," with over 25%). Thus, the local authorities could select strategies based on their specific condition.

- Bicycle planning and cycling trends in China

In China, the use and policies regarding cycling for transport have kept changing since the 1970s. During the 1970s and 1980s, cycling was one of the dominant transport modes (Frame, Ardila-Gomez, & Chen, 2017). The land use pattern at that time also facilitated the increasing bicycle use because residential areas and workplaces were often enclosed together as a unit (J. Yang, Chen, Zhou, & Wang, 2015). Since the 1990s, a rapid motorization process has taken place in big Chinese cities, resulting in a huge modal shift from AT to public transport and private motorized transport (Mehndiratta, 2012; M. Yang & Zacharias, 2016). The urban economic growth is connected closely with urban spatial growth, leading to the separation of residential areas and workplace and a longer commuting distance (Mehndiratta, 2012; Shaheen, Zhang, Martin, & Guzman, 2011; Su et al., 2014; C. Zhao, Nielsen, et al., 2018). Given the context that motorized transport was considered as an important facilitator to urban growth and a symbol of modernity, many cycle lanes were changed into motor traffic lanes with official policy guidance (Frame et al., 2017; Z. Li, Wang, Yang, & Ding, 2017; Mehndiratta, 2012; Pucher, Peng, Mittal, Zhu, & Korattyswaroopam, 2007). After 2000, the modal share of cycling in China has continued to decrease, with a rate of 3% per year (Z. Li et al., 2017). Although there is an increase in the use of electric bikes (e-bikes) (Cherry & Cervero, 2007; Z. Li et al., 2017), they are found to be problematic because e-bikes have caused a high rate of traffic accidents in many cities, partly due to the reckless travel behaviors of some e-cyclists (e.g., speeding, red light running) (Z. Li et al., 2017; H. Yang et al., 2018).

In 2012, the Chinese government officially announced that the explosion in car use was unsustainable and released guidelines for providing walking and cycling infrastructure (Frame et al., 2017). Cycling, as an environmentally friendly mode of transport, began to regain attention. Since 2016, there has been a rapid development in dockless bike-sharing (DBS) schemes. Mobike and Ofo, the two major bike sharing service providers, have provided millions of bikes in over 200 cities in China (Mobike, 2018; Ofo, 2018). Different from traditional bike-sharing schemes with docking stations, this type of public bike is high-tech equipped without specific stations for storing the bikes. The sufficient bike provision and convenient usage lead to a trend of “green travel” in China (Y. Sun, 2018). However, DBS schemes are also found to be problematic in many ways, including bike parking problems, vandalism to the bikes, and users’ distrust of the DBS operators (Y. Sun, 2018).

In comparison, Germany has a more supportive policy environment for cycling. While cycling is considered a separate mode of transport in many German cities, it is considered part of the nonmotorized transport available in Chinese cities. There is no national cycling policy framework in China. In contrast to many German cities, the promotion of cycling in China focuses more on encouraging public bicycle use rather than private bicycle use (J. Yang et al., 2015). Also, there is a higher share of e-bike use in China.

1.2.5 Knowledge gaps

First, while an increasing number of empirical studies have focused on the relationship between the built environment and AT, not enough literature reviews have analyzed the relationship between built environment and AT in a context-specific and domain-specific manner (Ding & Gebel, 2012; Grasser, Van Dyck, Titze, & Stronegger, 2013). Many of the empirical research have provided results derived from studies with different designs, for instance, using different analyzed geographic units. It is necessary to figure out whether different study designs may generate different results for better informing the decision-making. Also, the differences and similarities concerning the built environment correlation between walking for transport and cycling for transport have not been fully explored.

Second, although many studies have provided policy recommendations to promote cycling for transport, not enough studies have focused on barriers to implementing pro-cycling policies. Policy implementation is crucial to fully achieve the policy goals. Poor policy implementation might even reinforce people's nonrational mode of transport choice (Banister, 2005). Installing cycling infrastructure is cost-effective (Gössling & Choi, 2015; Macmillan, Witten, Kearns, D.Rees, & Woodward, 2014). However, in many car-oriented cities, it is hard to reallocate space for cycling infrastructure. Therefore, it is necessary to have a better understanding of barriers to pro-cycling policy implementation.

Third, an increasing number of cities around the world aim to increase cycling; however, many cities do not have a long tradition of bicycle planning, particularly in growing cities whose main focus is on motorization and modernization. There is insufficient understanding of the relationship between the growing city and bicycle planning practice (Mrkajić & Anguelovski, 2016) and of how bicycle planning is embedded in the local cultural context (C. Zhao, Carstensen, et al., 2018).

1.3 Research objectives and questions

Objective 1. Exploring the relationship between built environment and AT

<u>Research Questions</u>

- What are the recent findings on the relationship between the objectively measured neighborhood built environment and AT?
- Do different study designs generate different results?
- What directions can we provide for future research?

Objective 2. Exploring barriers to implementing pro-cycling policies

<u>Research Questions</u>

- What are the barriers to implementing pro-cycling policies in Hamburg?
- What are the underlying reasons for these barriers?

Objective 3. Understanding the bicycle planning culture and challenges in a growing city

<u>Research Questions</u>

- How do planners view cycling for transport in a growing megacity?
- What are the major challenges of improving cycling conditions?

- How do planners make practical judgments for deploying cycling infrastructure and what are their underlying perceptions and values?

Objective 4. Comparing bicycle planning in different contexts and exploring contextual influences

<u>Research Questions</u>

- What are the similarities and differences in bicycle planning in Hamburg and Wuhan?
- How do local contextual factors influence bicycle planning from the perspective of local experts?

1.4 Overview of methodology

Different methods and analytical frameworks are used to address the research questions (see Table 1.3).

Table 1.3. Overview of methodology

Objective	Method	Data collection	Data analysis
Objective 1 Understanding the relationship between built environment and AT (Chapter 2/ Paper I)	Systematic literature review	Systematic literature search based on the PRISMA statement (Liberati et al., 2009)	The PRISMA statement (Liberati et al., 2009)
Objective 2 Exploring barriers to implementing pro-cycling policies (Chapter 3/ Paper II)	Case study	Expert interviews, document survey, field observations	Qualitative content analysis (Schreier, 2012); barrier framework (Banister, 2005)
Objective 3 Understanding bicycle planning culture in a growing city (Chapter 4/ Paper III)	Case study	Expert interviews, questionnaire survey	Qualitative content analysis (Schreier, 2012); culturized planning model (Othengrafen & Reimer, 2013); descriptive and inferential statistics
Objective 4 Comparing bicycle planning in different contexts (Chapter 5)	Comparative case study	Data available from the two case studies (Papers II and III)	Culturized planning model (Othengrafen & Reimer, 2013)

To examine the relationship between the built environment and AT (Objective 1), a systematic literature review was conducted based on the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) statement (Liberati et al., 2009). The data search, selection, evaluation, and reporting were guided by a checklist with 27 items provided by the PRISMA statement. Peer-reviewed journal articles were searched with key terms in four electronic databases, namely Web of Knowledge, Scopus, PubMed, and Active Living Research. The articles were required to be published from January 1990 to March 2017 and were written in English.

To answer the research questions regarding Objective 2 and Objective 3, case studies were conducted in Hamburg, Germany and Wuhan, China. Hamburg is the second largest city in Germany with many pro-cycling policies being implemented. Wuhan is a rapidly growing city in China. The focus of the transport sector of Wuhan is on developing a rapid transit system. Expert interviews, document searches, and observations were conducted to collect data. These methods help in obtaining a comprehensive understanding of bicycle planning in case cities. Five semi-structured interviews were conducted with cycling professionals in Hamburg in 2017 and ten were conducted in Wuhan in 2017 and 2018. As regards the 15 interviews, eight were conducted face to face and seven were conducted by telephone. Profiles of the interviewees and the main interview questions are listed in Appendix A and Appendix B. A questionnaire survey (Appendix C) was conducted in Wuhan to examine to what extent the qualitative results can be generalized to a large sample. A total of 129 valid responses from Wuhan urban planners were collected. Documents regarding bicycle planning from official website and from interviewees are selected and analyzed. Since cycling infrastructure is observable, observations were conducted in each city several times and photos were taken to facilitate presenting of results.

After conducting the empirical studies in Hamburg and Wuhan, a comparative study was conducted to explore the similarities and differences in bicycle planning in different contexts (Objective 4). Guided by the culturized planning model (Othengrafen & Reimer, 2013), interview transcripts and planning documents from the two cities were analyzed.

1.5 Structure of the thesis

This thesis consists of six chapters, including three individual papers (Chapters 2–4) (see Table 1.4). Chapter 1 first describes the general background and the state of knowledge. Based on the knowledge gaps, four objectives with specific research questions are elaborated. Methods used for addressing the research questions are introduced.

Table 1.4. List of peer-reviewed publications included in the thesis

No.	Title of the Article	Author	Published in/ Submitted to
Paper I (Chapter 2)	The relationship between the neighborhood built environment and active transportation among adults: A systematic literature review	Luqi Wang, Chen Wen*	Published in: *Urban Science* (2017), 1(3), 29.
Paper II (Chapter 3)	Barriers to implementing pro-cycling policies: A case study of Hamburg	Luqi Wang	Published in: *Sustainability* (2018), 10(11), 4196.
Paper III (Chapter 4)	Planning for cycling in a growing megacity: Exploring practicing planners' perceptions and shared values	Luqi Wang	Submitted to *Cities*

*Author Contributions: LW conceived and designed the study; LW and CW performed the data search; LW analyzed the data and drafted the manuscript; CW revised the manuscript.

In Chapter 2 (Paper I), a systematic literature review on the relationship between objectively measured built environment factors and self-reported AT is conducted. Built environment correlates with walking for transport, cycling for transport, and AT in general are summarized separately.

Chapter 3 (Paper II) presents a case study in Hamburg exploring barriers to implementing pro-cycling policies. Five categories of barriers alongside underlying reasons are identified.

Chapter 4 (Paper III) presents a case study in Wuhan exploring the practicing planners' perceptions and shared values of bicycle planning.

Chapter 5 compares the bicycle planning culture in Hamburg and Wuhan based on materials from Chapter 3 and 4. Similarities and differences in bicycle planning process in the two cities are identified and discussed.

Chapter 6 synthesizes the findings of the three papers and the comparative study. Directions for future studies are proposed.

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2. The relationship between the neighborhood built environment and active transportation among adults: A systematic literature review (Paper I)

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Review

The Relationship between the Neighborhood Built Environment and Active Transportation among Adults: A Systematic Literature Review

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Abstract: Active transportation (AT) has aroused great interest in recent years as it may benefit public health and reduce the dependency on cars. This article aims to summarize recent findings on the relationship between the objectively measured built environment and AT among adults, to examine if different study designs may generate different results, and to provide directions for future research. A systematic literature review of journal articles from different databases was conducted. Fifty-one articles published between 2005 and 2017 were identified, and twelve built environment factors were extracted. The results showed that residential density, land use mix, street connectivity, retail land use, walkability, sidewalk, and access to destinations had a convincing positive relationship with walking for transport. Regarding cycling for transport, while street connectivity and bike lane showed a convincing positive relationship, neighborhood aesthetics and access to destinations showed a convincing negative relationship. Studies that use different analyzed geographic units and different measurements of AT may generate different results, so choosing suitable geographic units and measurement of AT is necessary to reduce the mismatch in the relationships. In addition, we need more longitudinal studies, more studies on cycling for transport, and more studies in countries outside North America and Australasia.

Keywords: active transportation; built environment; adults; review

1. Introduction

According to a World Health Organization fact file, lack of physical activity is one of leading risk factors for global mortality; it may also lead to non-communicable diseases such as diabetes, cardiovascular diseases, and cancer, seriously threatening public health [1]. To reduce the health risks of physical inactivity, active transportation (AT) has aroused great interest in recent years [2,3]. AT is any non-motorized travel based on human power, mostly referring to walking and cycling for transport, but also skiing, skateboarding, and using a wheelchair [4]. AT is also called non-motorized transportation, human powered transport, transport-related physical activity, and walking and cycling for utilitarian purposes [5]. Studies have confirmed several health benefits of AT [6,7]. AT has a beneficial impact on weight and cholesterol [8]. Compared with using private cars, walking to work is related to lower probability of obesity, hypertension, diabetes, and mental disorders [9]. Moreover, shifting from car use to AT may reduce air pollution, noise, and congestion [2]. Therefore, AT can be a promising way to facilitate public health [10].

Promoting AT depends on whether the built environment is supportive [1,11]. Previous studies showed that some built environment factors play roles in affecting AT. For example, AT might be related to access to destinations and walking and cycling infrastructure [12]. People are likely to walk or bike when the environment provides the destinations that are easy to access. To examine the relationship between the built environment and AT, an increasing number of studies have started using objective measurements of the built environment, especially using the Geographical Information System (GIS). Using objective measurements can explain the built environment in a more standardized way [13,14], and the research results may better help planners and policy makers to promote AT through the built environment [14]. However, existing empirical studies vary in research designs, such as the differences in study location, targeted population, audit tool, analyzed geographic unit, and study quality. The impact of study designs on the relationship between built environment and AT remains unclear.

For guiding relevant practitioners and future studies, many reviews synthesized existing knowledge about the relationship between built environment and AT. They have found that residential density [15–18], street connectivity [14–16,18], land use mix [14,16–19], walkability [15,16,19,20] and access to destinations [14,17,19,20] were positively related to AT. However, some of them have provided results that derived from different contexts (e.g., neighborhood, workplace) and different measurements (e.g., objectively measured, perceived) of built environment and AT, and some did not study walking and cycling for transport separately. Few literature reviews analyzed the relationship between built environment and AT in a context-specific and domain-specific manner [15,21]. Moreover, not enough literature reviews have explored the impact of study designs on the relationship between built environment and AT. A review that focuses on the objectively measured neighborhood built environment and AT is helpful to explore the role of the built environment in promoting AT. Therefore, this article aims to answer the following questions: (1) what are the recent findings on the relationship between the objectively measured neighborhood built environment and AT? (2) Do different study designs generate different results? (3) What directions can we provide for future research?

2. Materials and Methods

A systematic literature review method was adopted to synthesize the existing empirical studies. This review follows the guidance of the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) statement, which provides a detailed 27-item checklist that ensures a transparent meta-analysis report and systematic literature review [22]. This method was designed originally for clinical fields, but it can be used in other scientific fields [22]. To reduce bias and standardize the reporting of systematic literature reviews, the PRISMA statement is promoted to examine the relationship between the built environment and physical activity [23].

2.1. Search Strategy and Inclusion/Exclusion Criteria

The literature search was conducted across four electronic databases: Web of Knowledge, Scopus, PubMed, and Active Living Research. The publishing time of relevant articles was from January 1990 to March 2017. Articles were required to have been written in English and published in peer-reviewed journals. To ensure the quality of the selected studies, grey literature were not included in the search. Keywords that related to both AT and the built environment were used in title searches of the four databases. Terms, relevant synonyms, and spelling variations used to search for AT included: active transportation, physical activity, walk, cycle, bicycle, bike, commute, travel, and activity; those used to search for the built environment included: built environment, community, neighborhood, urban, metropolitan, street, and environment. In different databases, the search terms were adjusted according to the rules of the relevant databases. According to the PRISMA statement, there are four steps in the selection of publications: identification, screening, eligibility, and inclusion (see Figure 1). Two reviewers searched and selected independently and then discussed together to reach a consensus when finding disagreements or uncertainties.

In the selection of publications, there were four inclusion criteria:

- Objective measurement of the urban neighborhood environment.

- Transport-related physical activity measured with self-reported methods. Self-reported methods are most frequently used in obtaining physical activity data [16]. Therefore, we only focused on studies using self-reported physical activity data and excluded studies using objectively measured physical activity data.
- Mean age of study respondents of between 18 and 65 years old. Studies that solely focused on older adults (>65 years old) were excluded because older adults might have declined mobility [24], which might lead to a different relationship between built environment and AT.
- Quantitative studies with cross-sectional or longitudinal data.

During the full-text screening, 331 articles were excluded for the following reasons: (1) they assessed the urban neighborhood built environment only by perception; (2) the research area contained rural areas; (3) the measurements of physical activity were only related to recreational, moderate to vigorous, or general physical activity; (4) no analysis was made of the relationship between the built environment and AT; (5) articles were based on the same project with similar analysis and results (only one study of each of these was chosen).

After the full-text screening, 43 articles were included. Eight articles were identified from the reference of the included articles and other review studies. Finally, 51 [25–75] articles were included for the data extraction and analysis.

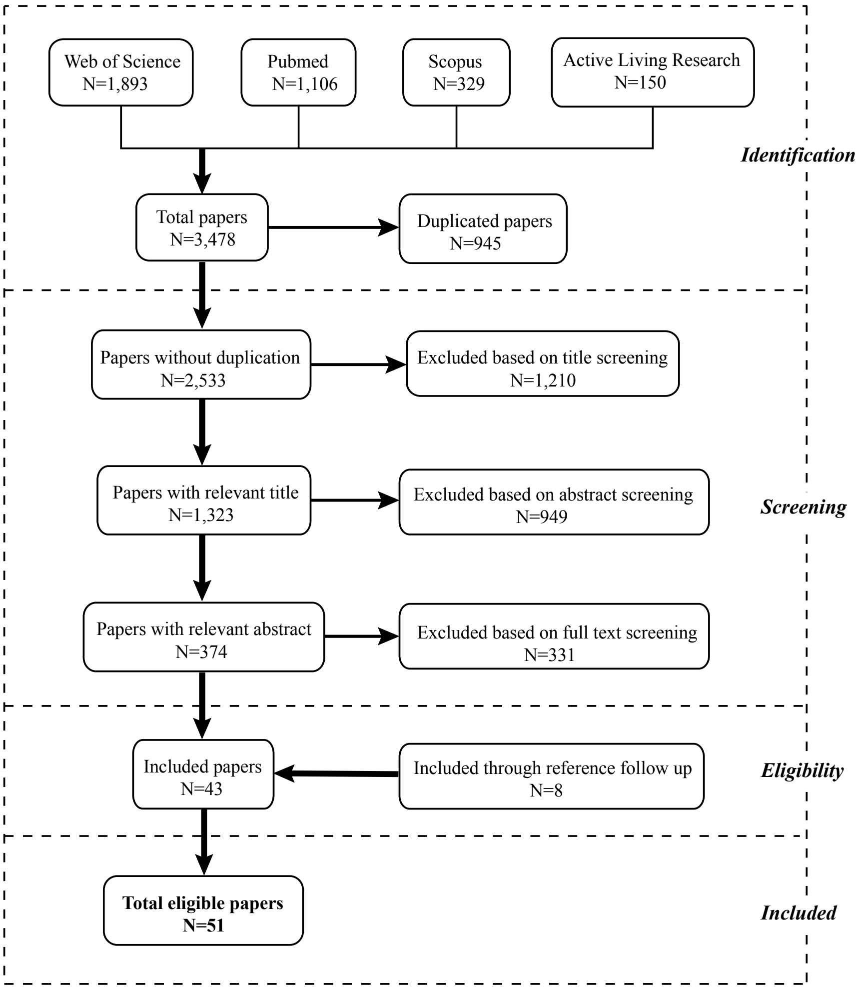

Figure 1. Flow of literature search process (based on the PRISMA flow diagram).

2.2. Data Extraction

In the analysis of the relationship between neighborhood built environment factors and AT, AT include walking for transport, cycling for transport and general AT. General AT means that the researchers did not separate walking and cycling when investigating respondents' AT.

The selection of the neighborhood built environment factors was based on the factors that were objectively measured in the retained 51 publications. Only built environment factors with clear descriptive results in more than one publication were selected. All the included studies used statistics to show their results. Most studies used p-values, with $p < 0.05$ indicating that the measured built environment factor is significantly related to physical activity. Some studies also chose 95% confidence intervals to determine significance. Finally, a total of twelve factors were selected. These twelve built environment factors include some relevant items that were used in different studies as described in Table 1.

Table 1. Summary of selected built environment factors.

Built Environment Factor	Relevant Items or Examples Used in Included Articles
Residential density	Population density; dwelling density
Land use mix	Land use diversity
Street connectivity	Intersection density; street crossing density
Retail land use	Retail area ratio; commercial land use; commercial intensity; density of services
Walkability	Walkability score; walkability index; Walk Score; active living potential
Street integration	The extent of access to a street segment or set of streets from other street segments or other parts of the city
Sidewalk	The presence or length of sidewalk; sidewalk/pedestrian network
Bicycle lane	The presence or density or length of bicycle lane; the proximity to bicycle lane; bicycle network connectivity
Access to destinations	The presence or number of a range of destinations; the proximity/access to shop, services, restaurant, bus stop/railway station, school, work, church, etc.
Traffic volume/speed	Traffic volume; traffic speed
Hilliness	Hill; slope
Neighborhood aesthetics	Presence of trees; green canopy coverage; greenness; green space; streetscape; the number of parks; park land use

2.3. Coding of Evidence

To categorize the relationship between AT and built environment factors, a method of evidence coding was used after adaptation from a previous literature review of Van Holle et al. [20]. The degree of the relationship was coded as three levels: unable to get a summary result, possible, and convincing (see Table 2). We only give a summary result to the built environment factor, for which more than four studies reached a conclusion.

Table 2. Criteria for coding summary results.

Type of results	Description	Code
Not able to get a summary result	0–4 studies reach a conclusion for the built environment factor; 0–40% of studies reach a conclusion in the same direction; 41–50% of studies reach a conclusion in the same direction and ≥25% in the opposite direction	-
Possible relationship	41–50% of studies reach a conclusion in the same direction and <25% in the opposite direction	*P*; *O*; *N*
Convincing relationship	51–100% of studies reach a conclusion in the same direction	**P**; **O**; **N**

- = Not able to get a summary result; *P* = possible positive relationship; *O* = possibly not related; *N* = possible negative relationship; **P** = convincing positive relationship; **O** = convincingly not related; **N** = convincing negative relationship.

2.4. Quality Assessment Criteria

The quality of these selected studies was assessed with a tool named the Effective Public Health Practice Project Quality Assessment Tool (EPHPP) [76,77] and its adapted version used by Grasser et al. [15]. The EPHPP tool has been confirmed to have an excellent agreement for its final grading [78]. It is a suitable tool for assessing the quality of quantitative research with various study designs. Because the majority of the selected studies used cross-sectional data, this assessment tool was adapted to assess four components regarding the studies' methodological quality: response rate, representativeness, outcome measures, and confounding factors (further description presented in Table 3). Under assessment of confounding factors, self-selection adjustment was added as a criterion, as it might affect the accuracy of the result regarding the relationship between the built environment and physical activity [14,25]. Generally, self-selection means that people who like to be physically active tend to choose to live in a neighborhood that can better support physical activity [25]. In the included studies, self-selection factors contain the respondents' attitudes towards AT, preference for a more/less walkable neighborhood to live in, and other factors related to psychosocial aspects.

Table 3. Criteria used in the quality assessment.

Component	Explanation	Score
Response rate	The overall response rate of the questionnaire survey of physical activity	• 0: unknown or ≤5% • 1: 5%–20% • 2: ≥20%
Representativeness	Whether the study sample could represent the target population	• 0: unknown or not representative • 1: partly representative • 2: representative
Outcome measures	Whether the study used a valid questionnaire	• 0: unknown or not valid • 1: unknown but used local city/national household survey data • 2: valid
Confounding factors	Whether the study controlled for socioeconomic factors and self-selection factors	• 0: not controlled • 1: only controlled for socioeconomic factors • 2: controlled for both socioeconomic factors and self-selection factors
Final grade	The final result of the quality assessment after summing up the scores above	• Weak: 0, 1, 2, 3 • Moderate: 4, 5 • Strong: 6, 7, 8

3. Results

3.1. Study Characteristics

We extracted several characteristics of included studies (see Table 4). Regarding the year of publication, although the timeframe for the search is from 1990 to 2017, it appears that the earliest year an eligible article was published is 2005 [72]. Fifteen (29.4%) studies were published between 2005 and 2009, and 36 (70.6%) studies were published after 2010, particularly in 2014 and 2016, each year with ten articles. This indicates rapidly increasing interest in this research area in recent years. Regarding the study location, 23 (45.1%) studies were taken in North America, of which 16 were in the United States, and seven were in Canada. Nine (17.6%) studies were conducted in Australia and one in New Zealand. Nine (17.6%) studies were carried out in European countries. Six studies were conducted in Asia and two studies in South America. Two studies were cross-national studies, with one study [62] containing five European countries and the other one [69] containing ten countries from four continents. All the studies examined both male and female subjects. The least number of sample size was 72 [29]. Thirty-one (60.8%) studies have a sample size between 500 and 3000. Twelve (23.5%) studies have a sample size over 5000 respondents.

The majority of studies (92.2%) only used cross-sectional data, and four studies [26–28,60] used longitudinal data. Twenty-eight (54.9%) studies exclusively focused on walking for transport, and ten (19.6%) studies exclusively focused on cycling for transport. Seven studies examined walking and cycling for transport separately, and six studies examined general AT. The measurements of walking and/or cycling for transport included participation (e.g., respondents reported whether or not they used AT in the last week), frequency (e.g., respondents reported how many times they used AT in the last week), and duration (e.g., respondents reported how much time they spent on AT in the last week).

Regarding the objective measurements of the built environment, GIS technique was widely used (70.6%). Although all these 51 studies have focused on the neighborhood built environment, they used different analyzed geographic units. Twenty-nine (56.9%) studies measured the area within certain distances around each respondent's home address (e.g., 500 m street network distance around each respondent's home). Twelve (23.5%) studies used the stable geographical areas (e.g., neighborhoods defined by local administrations, census tracts, or statistical sectors). Eight (15.7%) studies measured the area within certain distances around the neighborhood. For the studies that provided a specific radius for buffer size, the distance ranged from 200 m to 3500 m.

Table 4. Summary of study characteristics.

Author, (Year), Reference	Location, Sample Size	Mean Age/Age Range (Years)	Objective Measures of Built Environment	Travel Mode	Analyzed Geographic Unit
McCormack et al. (2012) [25]	Australia, 1681	40.2	GIS-based measures	1	1.6-km road network buffer around home address
Knuiman et al. (2014) [26]	Australia, 1703 (baseline [d])	39.9	GIS-based measures	1	1.6-km road network buffer around home address
Kamruzzaman et al. (2016) [27]	Australia, 3612 (baseline)	40–70	Archival datasets [e]	1	1-km circular buffer around home address
Wasfi et al. (2016) [28]	Canada, 2976 (baseline)	18–55	Walk Score metric	1	Walk Score based on residential location
Miles et al. (2008) [29]	USA, 72	40; 44	GIS-based measures; direct observations	1	402-m, 805-m, 1609-m of the center of the neighborhoods
Lee and Moudon (2006) [30]	USA, 438	≥18	GIS-based measures	1	Land use and infrastructure: 1-km around home address; access to destination: 3-km around home address; density: parcel level and 1-km around home address
Handy et al. (2006) [31]	USA, 1672	43.3; 54.7	GIS-based measures	1	400-m, 800-m, 1600-m street network buffer around home address
Pikora et al. (2006) [32]	Australia, 1678	18–59	SPACES [c] instrument	1	400-m radius buffer around home address
Forsyth et al. (2007) [33]	USA, 715	44/49	GIS-based measures	1	805 × 805 m^2; 0.2-km, 0.4-km, 0.8-km, 1.6-km street network and straight-line buffer around home address
Rodríguez et al. (2009) [34]	USA, 5529	45–84	GIS-based measures	1	200-m radius buffer around home address
Sundquist et al. (2011) [35]	Sweden, 2269	20–66	GIS-based measures	1	Neighborhood based on administrative area
Carlson et al. (2012) [36]	USA, 679	52	Built environment metrics	1	Neighborhood based on administrative area
Karusisi et al. (2014) [37]	France, 7290	30–79	GIS-based measures	1	500-m street network radius buffer around home and workplace

Table 4. *Cont.*

Author, (Year), Reference	Location, Sample Size	Mean Age/Age Range (Years)	Objective Measures of Built Environment	Travel Mode	Analyzed Geographic Unit
Sung et al. (2014) [38]	Korea, 1826	39.6	GIS-based measures	1	250-m, 500-m, 1000-m, 1500-m circular buffers around home
Jack and McCormack (2014) [39]	Canada, 1875	≥18	GIS-based measures	1	1.6-km street network buffer around home address
Reyer et al. (2014) [40]	Germany, 1871	54.1	GIS-based measures; Walk Score metric	1	Walk Score: 500-m area around home address
Thielman et al. (2015) [41]	Canada, 151,318	>12	Walk Score metric	1	Walk Score values were assigned to postal codes and a single postal code can include multiple respondents
Owen et al. (2007) [42]	Australia, 2650	20–65	GIS-based measures	1	Census Collectors' Districts
Tilt et al. (2007) [43]	USA, 529	≥18	GIS-based measures	1	0.4-mi street networks buffer of residential parcels
Saelens et al. (2012) [44]	USA, 2199	45.2	GIS-based measures	1	1-km street network buffer around home address
Riva et al. (2009) [45]	Canada, 2716	≥45	GIS-based measures	1	Dissemination area-level: stable geographic units composed of one or more neighboring street blocks, with a population of 400–700 persons
Turrell et al. (2013) [46]	Australia, 10,711	40–65	Archival datasets	1	Census Collectors' Districts
Wineman et al. (2014) [47]	USA, 460	50.9	GIS-based measures	1	Street connectivity and integration: 0.5-mi radius from survey participant's residential block; density and land use mix: 0.25-mi, 0.5-mi radius
Oliver et al. (2011) [48]	Canada, 1602	47	GIS-based measures	1	1-km road network buffer around each respondent's postal code
Koohsari et al. (2017) [49]	Japan, 569	55.8	GIS-based measures	1	Intersection density: 800-m radius buffer around home address; Street integration: 1-km radius buffer
Larrañaga et al. (2016) [50]	Brazil, 442 household	43	GIS-based measures	1	500-m buffer from the geometric center of the census tract of residence
Kelley et al. (2016) [51]	USA, 906	55	Walk Score metric	1	Walk Scores base on home address
Koohsari et al. (2017) [52]	Australia, 16,345	46.6	Archival datasets; Walk Score metric	1	Statistical Area 1 (the smallest geographic unit in Australia)
Dill and Voros (2007) [53]	USA, 566	≥18	GIS-based measures	2	0.25-mi buffer around home address
Owen et al. (2010) [54]	Australia, 1940	45.4	GIS-based measures	2	Census Collectors' Districts
Rybarczyk and Wu (2014) [55]	USA, 6210	18–74	GIS-based measures	2	3-km straight-line buffers around home address
Zhao (2014) [56]	China, 613	48.1; 43.7	Archival datasets	2	3.5-km radius from the centroid of a community
Foster et al. (2011) [57]	UK, 13,927	41–80	GIS-based measures	2	0.5-km, 1-km, 2-km, 3.2-km buffers around home address
Ma and Dill (2015) [58]	USA, 616	51.3	GIS-based measures	2	0.5-mi circular and network buffers around home address
Heesch et al. (2015) [59]	Australia, 10,328	40–65	GIS-based measures	2	Neighborhood suburbs (a median of 3.9 km^2 in size)
Zahabi et al. (2016) [60]	Canada, 21,188 (baseline);	≥15	GIS-based measures	2	500-m grid cell level
Braun et al. (2016) [61]	Spain, 765	18–65	GIS-based measures	2	400-m circular buffer around home address
Mertens et al. (2017) [62]	Five countries [a], 3904	45.5	SPOTLIGHT Virtual Audit Tool	2	In Hungary: 1 km^2 areas in greater Budapest; in other countries: neighborhoods based on local administrative boundaries
Kondo et al. (2009) [63]	Japan, 156	51.0; 53.8	GIS-based measures	3	500-m radius buffer around home address
Cervero et al. (2009) [64]	Colombia, 1285	≥18	GIS-based measures	3	500-m straight-line radius around the sampled neighborhoods; and 1000-m straight-line beyond the perimeters of sampled neighborhoods
Van Dyck et al. (2009) [65]	Belgium, 120	43	Field observations, geographical map data	3	800-m radius buffer around home address
Van Dyck et al. (2010) [66]	Belgium, 1166	42.7	GIS-based measures	3	Neighborhood based on statistical sectors
Fan et al. (2014) [67]	USA, 39,660 census tracts	37.7	GIS-based measures	3	Census tract (between 1200 and 8000 residents)

Table 4. *Cont.*

Author, (Year), Reference	Location, Sample Size	Mean Age/Age Range (Years)	Objective Measures of Built Environment	Travel Mode	Analyzed Geographic Unit
Munshi (2016) [68]	India, 2050	38; 39; 40; 44	Archival datasets	3	100-m equal size grid cell level
Christiansen et al. (2016) [69]	Ten countries [b], 12,181	18–66	GIS-based measures	3	500-m and 1-km street-network buffer around home address
Witten et al. (2012) [70]	New Zealand, 2033	20–65	GIS-based measures and SPACES [c] instrument	4	Accessibility: 800-m along street network of a meshblock centroid; other variables: at the meshblock level
Frank et al. (2006) [71]	USA, 1228	44	Archival datasets	4	1-km street network buffer around home address
Hoehner et al. (2005) [72]	USA, 1053	18–96	Environmental audits	4	400-m buffer around home address
de Sa and Ardern (2014) [73]	Canada, 1158	47.9	GIS-based measures	4	500-m radius buffer around home address
Mäki-Opas et al. (2016) [74]	Finland, 2098	30–64	GIS-based measures	4	The pedestrian and cycling network within 500-m buffer around home address
Feng (2016) [75]	China, 5051	≥20	Archival datasets	4	1-km radius circle buffer around the center of each traffic analysis zone

1 = the study only measured walking for transport; 2 = the study only measured cycling for transport; 3 = the study measured walking and cycling for transport as separate variables; 4 = the study measured walking and cycling transport as one variable; km = kilometer; m = meter; mi = mile; [a] Belgium, France, Hungary, Netherlands, and UK; [b] Australia, Belgium, Brazil, Colombia, Czech Republic, Denmark, Mexico, New Zealand, United Kingdom, and United States; [c] Systematic Pedestrian and Cycling Environmental Scan instrument; [d] In longitudinal studies, only the sample size of baseline was shown here; [e] Archival datasets means the research used available built environment datasets (e.g., spatial data from local planning authority), but the audit tool or analyzed tool was not explicitly elaborated.

3.2. Results of Quality Assessment

The results of the quality assessment of each study are presented in Table 5. Overall, 22 (43.1%) studies were of strong quality, 21 (41.2%) were of moderate quality, and eight (15.7%) were of weak quality. The majority of studies (68.6%) had an overall response rate above 20%, 12 (23.5%) studies had below 5% or not provided. Only 13 (25.5%) studies claimed to have used a representative sample. Twenty-five (49.0%) studies claimed to have used a valid questionnaire in acquiring AT data. The International Physical Activity Questionnaire (IPAQ) was used widely (33.3%) and has been proved to have acceptable validity and reliability [79]. Twelve studies (23.5%) did not mention the validity and reliability of their self-reported surveys. All the 51 studies have controlled for socioeconomic factors in their statistical analysis. Eighteen (35.3%) studies also controlled for self-selection factors.

In general, studies that focused on walking and general AT were of higher quality than studies that focused on cycling. For the studies that only examined walking for transport, 13 out of 28 studies were of strong quality. For the studies that only studied cycling for transport, only one [59] out of ten studies was of strong quality. Regarding the studies that examined general AT, five out of six were of strong quality.

Table 5. Summary of quality assessment results.

Author, (Year), Reference	Response Rate	Representativeness	Outcome Measures	Confounding Factors	Global Rating	
McCormack et al. (2012) [25]	2	0	2	2	6	Strong
Knuiman et al. (2014) [26]	2	0	2	2	6	Strong
Kamruzzaman et al. (2016) [27]	2	2	2	2	8	Strong
Wasfi et al. (2016) [28]	2	2	1	2	7	Strong
Miles et al. (2008) [29]	0	2	2	1	5	Moderate
Lee and Moudon (2006) [30]	2	1	2	2	7	Strong
Handy et al. (2006) [31]	2	1	0	2	5	Moderate
Pikora et al. (2006) [32]	2	0	0	2	4	Moderate
Forsyth et al. (2007) [33]	0	1	2	1	4	Moderate
Rodríguez et al. (2009) [34]	2	0	2	1	5	Moderate
Sundquist et al. (2011) [35]	2	1	2	1	6	Strong
Carlson et al. (2012) [36]	2	1	1	1	5	Moderate
Karusisi et al. (2014) [37]	2	1	0	1	4	Moderate
Sung et al. (2014) [38]	0	1	1	1	3	Weak
Jack and McCormack (2014) [39]	2	0	2	2	6	Strong
Reyer et al. (2014) [40]	0	1	1	1	3	Weak
Thielman et al. (2015) [41]	2	2	1	1	6	Strong
Owen et al. (2007) [42]	1	1	2	2	6	Strong
Tilt et al. (2007) [43]	1	1	1	1	4	Moderate
Saelens et al. (2012) [44]	2	0	2	2	6	Strong
Riva et al. (2009) [45]	2	2	2	1	7	Strong
Turrell et al. (2013) [46]	2	2	0	1	5	Moderate
Wineman et al. (2014) [47]	2	1	2	1	6	Strong
Oliver et al. (2011) [48]	2	0	0	1	3	Weak
Koohsari et al. (2017) [49]	2	1	2	1	6	Strong
Larrañaga et al. (2016) [50]	2	1	0	2	5	Moderate
Kelley et al. (2016) [51]	2	2	0	1	5	Moderate
Koohsari et al. (2017) [52]	2	1	1	1	5	Moderate
Dill and Voros (2007) [53]	2	0	0	2	4	Moderate
Owen et al. (2010) [54]	1	0	2	1	4	Moderate
Rybarczyk and Wu (2014) [55]	0	1	1	1	3	Weak
Zhao (2014) [56]	0	2	0	1	3	Weak
Foster et al. (2011) [57]	0	2	1	1	4	Moderate
Ma and Dill (2015) [58]	2	1	0	2	5	Moderate
Heesch et al. (2015) [59]	2	2	0	2	6	Strong
Zahabi et al. (2016) [60]	0	1	1	2	4	Moderate
Braun et al. (2016) [61]	2	1	0	1	4	Moderate
Mertens et al. (2017) [62]	1	0	2	1	4	Moderate
Kondo et al. (2009) [63]	2	0	2	1	5	Moderate
Cervero et al. (2009) [64]	2	2	2	1	7	Strong
Van Dyck et al. (2009) [65]	2	1	2	2	7	Strong
Van Dyck et al. (2010) [66]	2	1	2	1	6	Strong
Fan et al. (2014) [67]	0	1	1	1	3	Weak
Munshi (2016) [68]	0	1	0	2	3	Weak
Christiansen et al. (2016) [69]	0	1	2	1	4	Moderate
Witten et al. (2012) [70]	2	1	2	2	7	Strong
Frank et al. (2006) [71]	2	1	2	1	6	Strong
Hoehner et al. (2005) [72]	2	1	2	1	6	Strong
De Sa and Ardern (2014) [73]	2	2	1	1	6	Strong
Mäki-Opas et al. (2016) [74]	2	2	2	1	7	Strong
Feng (2016) [75]	0	1	1	1	3	Weak

3.3. Relationship between Neighborhood Built Environment and AT

Among the twelve built environment factors, street connectivity (n = 18) was most frequently reached a conclusion in the included studies, followed by residential density (n = 16), access to destinations (n = 16), and walkability (n = 15). Studies with different levels of quality were all categorized to generate a final summary result, and studies of weak quality were marked with "*" in the following tables.

3.3.1. Walking for Transport

Thirty-five studies examined the relationship between the built environment and walking for transport (Table 6). We found convincing positive relationships between walking for transport and residential density, land use mix, street connectivity, retail land use, walkability, sidewalk, and access to destinations. In addition, we found neighborhood aesthetics was not related.

Table 6. Summary of relationships between built environment and walking for transport.

Built Environment Factors	Positive Relationship	Not Related	Negative Relationship	Overall Results	
				A	B
Residential density	[27] [29] [30] [33] [34] [50] [67] * [68] *	[26] [30] [30] [63] [64]	[30] [47]	8/15	**P**
Land use mix	[26] [38] * [38] * [46] [48] * [68] * [69]	[48] * [64]		7/9	**P**
Street connectivity	[26] [27] [27] [36] [44] [46] [49] [50] [64] [67] *	[37] [63] [64]		10/13	**P**
Retail land use	[34] [38] * [44] [48] * [50]			5/5	**P**
Walkability	[25] [28] [32] [35] [39] [39] [40] * [40] * [41] [42] [45] [51] m [52] [65] [66]	[25] [42] [51] f		15/18	**P**
Street integration	[47] [52]	[49]		2/3	-
Sidewalk	[25] [25] [32] [36]	[30] [63]		4/6	**P**
Access to destinations	[26] [29] [30] [31] [32] [37] [38] * [38] * [43] [64]	[64]	[67] *	10/12	**P**
Traffic volume/speed		[30] [32]		2/2	-
Hilliness			[30] [50] [64]	3/3	-
Neighborhood aesthetics	[48] *	[30] [32] [43]	[67] *	3/5	**O**

* Studies of weak quality; f female subjects; m male subjects; **A** = number of the most common results divided by number of all results; **B** = summary code; - = not able to get a summary result; **P** = convincing positive relationship; **O** = convincingly not related.

3.3.2. Cycling for Transport

Seventeen studies provided results of relationships between cycling for transport and built environment factors (Table 7). Street connectivity and bike lane were most frequently examined, and both were found to have a convincing positive relationship with cycling for transport. Neighborhood aesthetics and access to destinations showed convincing negative relationships.

Table 7. Summary of relationships between built environment and cycling for transport.

Built Environment Factors	Positive Relationship	Not Related	Negative Relationship	Overall Results	
				A	B
Residential density	[68] *	[56] * [61] [63]		3/4	-
Land use mix	[56] * [63] f [69]	[63] m		3/4	-
Street connectivity	[53] [55] * [56] * [60] [67] * [69]	[63]		6/7	**P**
Retail land use		[61]		1/1	-
Walkability	[54] [66]	[65]		2/3	-
Sidewalk		[63]		1/1	-
Bicycle lane	[56] * [58] [58] [60] [61] [62]	[53] [61] [64]		6/9	**P**
Access to destinations	[58] [59]		[56] * [58] [61] [67] *	4/6	**N**
Traffic volume/speed		[57]	[62]	1/2	-
Hilliness			[64]	1/1	-
Neighborhood aesthetics	[62]	[69]	[55] * [62] [67] *	3/5	**N**

* Studies of weak quality; f female subjects; m male subjects; **A** = number of the most common results divided by number of all results; **B** = summary code; - = not able to get a summary result; **P** = convincing positive relationship; **N** = convincing negative relationship.

3.3.3. General AT

Only six studies [70–75] investigated the relationship between built environment factors and general AT (Table 8). No possible or convincing evidence was concluded because of limited evidence appeared.

Table 8. Summary of relationships between built environment and general active transportation.

Built Environment Factors	Positive Relationship	Not Related	Negative Relationship	Overall Results	
				A	B
Residential density	[70] [73]			2/2	-
Land use mix		[75] *		1/1	-
Street connectivity	[70] [75] *			2/2	-
Walkability	[71]			1/1	-
Sidewalk	[74] [75] *			2/2	-
Bicycle lane	[74] [75] *			2/2	-
Access to destinations	[70] [72]			2/2	-
Neighborhood aesthetics	[75] *	[73]	[72] [74]	2/4	-

* Studies of weak quality; A = number of the most common results divided by number of all results; B = summary code; - = not able to get a summary result.

3.3.4. Inconsistent Results from Studies with Different Designs

To examine the impact of study designs on the relationship between built environment factors and AT, a summary of inconsistent results from studies with different designs was showed in Table 9. Two studies [30,64] found inconsistent results when using different analyzed geographic units. Five studies [25,30,42,58,62] found inconsistent results when using different measurements of AT. One study [48] found inconsistent relationships between land use mix and walking to different destinations.

Table 9. Summary of inconsistent results from studies with different designs.

Built Environment Factors	Reference	Result
Residential density	[30]	• Parcel level density was positively related to the frequency of walking for transport and not related to the participation in walking for transport • Area level density was not related to the frequency of walking for transport and negatively related to the participation in walking for transport
Land use mix	[48]	• Land use mix was positively related to walking for errands • Land use mix was not related to walking to work/school
Street connectivity	[64]	• 500-m buffer: street connectivity was positively related to walking for transport • 1000-m buffer: street connectivity was not related to walking for transport
Walkability	[25]	• Walkability was positively related to the participation in walking for transport • Walkability was not related to the duration of walking for transport
	[42]	• Walkability was positively related to the frequency of walking for transport • Walkability was not related to the duration of walking for transport
Bicycle lane	[61]	• Bicycle lane was not related to cycling for transport • Bicycle network connectivity was positively related to cycling for transport

Table 9. *Cont.*

Built Environment Factors	Reference	Result
Access to destinations	[58]	• Access to retail jobs was positively related to the frequency of cycling for transport • Access to retail jobs was negatively related to the participation in cycling for transport
	[64]	• 500-m buffer: access to destination was not related to walking for transport • 1000-m buffer: access to destination was positively related to walking for transport
Neighborhood aesthetics	[62]	• Presence of trees was positively related to the participation in cycling for transport • Presence of trees was negatively related to the duration of cycling for transport

4. Discussion

4.1. Summary of Evidence

According to the review of 51 studies, we found that most studies examined factors related to walkability and accessibility, and only a few studies examined traffic volume and hilliness. Many factors showed convincing positive relationship with walking for transport, including residential density, land use mix, street connectivity, retail land use, walkability, sidewalk, and access to destinations. Neighborhood aesthetics showed no relationship. Regarding cycling for transport, while street connectivity and bike lane showed a convincing positive relationship, neighborhood aesthetics and access to destinations showed a convincing negative relationship. We were not able to reach a conclusion regarding the general AT because of the limited number of studies.

4.1.1. Comparison of Results between Walking and Cycling for Transport

Regarding the overall results, while street connectivity showed a convincing positive relationship with both walking and cycling for transport, access to destinations and neighborhood aesthetics showed inconsistent results. Particularly, access to destinations showed opposite results between walking and cycling for transport. Two studies [56,61] found that access to public transit services was negatively related to cycling for transport. It is possible that people who have easy access to public transport would choose to use it rather than cycling. Furthermore, neighborhood aesthetics showed no relationship with walking for transport but did show a convincing negative relationship with cycling for transport. It is possible that green space or parks might lead to a long travel distance [67] and unsafe perception of cyclists [55].

Regarding the seven studies [63–69] that examined both walking and cycling for transport, two studies [65,69] found inconsistent results. Christiansen and colleagues [69] conducted an international comparative study, and they found that intersection density was linearly positively related to cycling for transport, but not linearly related to walking for transport. They suggested that there might be optimum values of built environment factors to better facilitate AT. Van Dyck et al. [65] found that walkability was positively related to walking for transport, but not related to cycling for transport. Overall, we should consider the differences between walking and cycling, and particularly the differences in their relationships with built environment.

4.1.2. Comparison with Existing Literature Reviews

Generally, our study confirmed some results of existing literature reviews [14–20]: residential density, street connectivity, and land use mix, walkability and access to destinations are positively related to walking for transportation. Our review also found that only a small proportion of studies focused on cycling and general AT, which is in line with existing reviews [15,80]. The more focus on walking is possibly because walking is more popular than cycling as a daily physical activity, especially in North American countries. Even so, we found that more and more studies on cycling were conducted in North America. While only five [53,55,58,60,67] out of 28 studies that took place in North America examined cycling, four [55,58,60,67] out of the five were published since 2014.

Moreover, we found that bike lanes were positively related to cycling for transport, which was in accordance with the review of Fraser and Lock [81]. However, the findings of a negative relationship with neighborhood aesthetics and access to destinations (especially public transport) were not in agreement with the reviews of Fraser and Lock and Van Holle et al. [20,81]. Fraser and Lock [81] found that proximity to green space was positively related to cycling for transport. Van Holle et al. [20] found that aesthetics and access to public transport were not related. The inconsistency of the results is probably because only a few studies focused on cycling for transport, which might lead to the unrepresentative and inaccurate results.

4.2. Differences in the Results of Studies with Different Designs

4.2.1. Study Location

While 21 countries were included in the 51 studies, we found it hard to identify the differences in results between different countries because only a small number of studies were conducted outside North America and Australasia. Four studies [35,40,65,66] in Europe found that walkability was positively related to walking for transport, and the results were in agreement with the findings of North America and Australasia studies and a review that focused on European adults [20]. Moreover, although most included studies were conducted in high-income countries, studies from the USA, Australia, and Belgium all confirmed that residents in the neighborhood with a higher level of socioeconomically disadvantage walked more for transport [29,46,66]. It is understandable that residents in the socioeconomically disadvantaged neighborhood might have less access to private cars, thus contributing to a higher level of AT [29,46]. While most studies in the USA found that residential density was positively related to walking for transport, one study found a negative relationship in socioeconomically disadvantaged neighborhoods in Detroit [47]. It is possible that residents in the socioeconomically disadvantaged neighborhood have a higher perception of crime that indicates a modifying influence on the relationship between walking for transport and built environment [47]. However, the geographical and cultural backgrounds in different continents are different, which might affect the relationship between built environment and AT. For instance, European cities tend to have a more compact urban structure, while the majority of cities in the United States have a scattered urban pattern due to the urban sprawl development [20]. Previous studies have found that the use of bicycles in some European countries was ten times greater than the use in America [53,82]. To further identify the differences of built environment relationships with AT in different countries, more empirical studies from different contexts are necessary.

4.2.2. Study Quality

Regarding studies of different quality, studies that were assessed as having weak quality did not show obviously different results with studies of moderate or strong quality. Self-selection, another major concern proposed in previous studies [14,21,25,31], also did not show a strong influence on the relationship between the built environment and AT. Only one study found that, after controlling for the self-selection factor, walkability was not related to the weekly minutes of walking for transport, but it was still positively related to the frequency of walking for transport [42]. Other studies have confirmed that built environment was related to AT even after controlling for self-selection. This finding is consistent with one previous review study [16]. It is promising that several built environment factors may facilitate AT after considering self-selection factors [16]. However, only 18 out of 51 studies examined self-selection factors in this review; future studies need further examine the role of self-selection in affecting the relationship between built environment and AT.

4.2.3. Analyzed Geographic Unit and Different Measurements of AT

Some inconsistent evidence appeared when studies adopted different analyzed geographic units [30,64]. These inconsistencies showed that it remains unclear which geographic unit could measure the relationship between the built environment and walking for transport most accurately. As a result, future studies should be aware that using different analyzed geographic units might lead to different results, and researchers should consider proper geographic units for different built environment factors to explain the relationships accurately.

Two studies in Australia found that walkability had inconsistent relationships with different measurements of walking for transport [25,42]. It is possible that a more walkable neighborhood may encourage more walking episodes and reduce the duration of each episode [42]. Ma and Dill [58] found that access to retail was positively related to the frequency of cycling for transport, but negatively related to the participation in cycling for transport. It is possible that for the people who were not used to cycling, they might choose walking rather than cycling when they live close to destinations, but frequent cyclists might still cycle more if they have higher access to destinations [58]. However, these inconsistencies show that we need to distinguish the different measurements of AT to avoid the mismatch in the relationship between built environment and AT.

4.3. Limitation and Implications for Future Research

4.3.1. Limitation of the Included Studies

The main limitation of the included studies might be that 47 out of the 51 studies only used cross-sectional data, which cannot contribute to the demonstration of a causal relationship between the built environment and physical activity. Regarding the quality of the included studies, we marked "0" in the corresponding categories of quality assessment when some studies did not show the representative of study sample and reliability and validity of AT data. It is possible that some of these studies did use representative samples or reliable and valid AT data but ignored to show the details in their texts. Moreover, there might be a mismatch between neighborhood built environment and AT. For example, several studies measured the neighborhood built environment, but the AT data were referring to the amount of AT that happened both in and outside the neighborhood. It would be more accurate to analyze the relationship between neighborhood built environment and within-neighborhood AT. In addition, only a few studies investigated general AT and cycling for transport, which might lead to limited evidence or biased results in concluding the results regarding general AT and cycling for transport.

4.3.2. Limitation of the Systematic Review

There are several limitations related to the review method. First, to ensure the quality of selected studies, this review only includes articles that were published in peer-reviewed journals. It is possible that some valuable evidence in grey literature was missed. Second, 33 out of the 51 studies were conducted in North American and Australasian countries, and only a few studies took place in Europe, Asia, and South America. This is possibly because this review only searched publications written in English. Given the differences in travel behavior in different geographical contexts, the conclusions of this review may not generalize to different geographic regions [20]. Third, some biases might exist in data extraction process. For instance, some studies conducted several analysis models, but we only selected and summarized the results of the more comprehensive model and linear relationship. Therefore, the results in the summary tables might be slightly different from the conclusion of the original studies.

4.3.3. Implication for Future Research

First, future studies should pay more attention to cycling behavior and cycling environment. Cycling can be a promising way to replace private car use for short trips, and it can be more effective than walking in enhancing health because it is more intensive [10,83].

Second, future studies should figure out that at which geographic unit should different built environment factor be measured to increase the accuracy of the result. For future studies that examine the cycling environment, a larger buffer size is needed as cycling is faster and the travel distance is longer than walking [69]. For instance, a previous study has suggested that a suitable buffer size should be 3 km (a 20-min cycling range) for examining cycling behavior [84].

Third, future studies should further explore the role of self-selection factors and distinguish the differences in the relationship between built environment factors and different measurements of AT.

Fourth, we need more studies in continents other than North America and Australasia and more longitudinal studies to better understand the relationship between the built environment and AT in different contexts.

5. Conclusions

Overall, this review found that several built environment factors were related to walking for transport, even in studies that have controlled for self-selection factors. Factors related to walkability (walkability index, street connectivity, residential density and land use mix), retail land use, sidewalk, and access to destinations were more often found to have a convincing positive relationship with walking for transport. Neighborhood aesthetics showed no relationship. Regarding cycling for transport, street connectivity and bike lane showed a convincing positive relationship. Neighborhood aesthetics and access to destinations showed a convincing negative relationship. The differences in the relationship of built environment with walking for transport and with cycling for transport indicate the need for separating the research on different forms of AT. Moreover, this review found that studies using different analyzed geographic units could generate different results, indicating the need for using more suitable geographic units to explain the relationships accurately. This review also found that built environment factors had inconsistent relationships with different measurements of AT, and future studies should distinguish the different measurements of AT to avoid the mismatch in the relationships between built environment and AT. To increase people's daily physical activity level and reduce the dependency on cars, it is essential to create a walking and cycling friendly environment. This review may contribute to the understanding of how to promote AT through the built environment and have implications for urban planners and policy makers.

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3. Barriers to implementing pro-cycling policies: a case study of Hamburg, Germany (Paper II)

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Barriers to Implementing Pro-Cycling Policies: A Case Study of Hamburg

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Abstract: Cycling is gaining increasing attention as a convenient, environmentally friendly, and fitness-improving mode of transport. While many policy interventions have been made to promote cycling, not enough research has focused on the barriers to implementing pro-cycling policies. For effective policy implementation, identifying major barriers and removing them is critical. This study took an in-depth look at Hamburg which started a major cycling promotion in 2008. According to expert interviews and literature surveys, the author found that the major barriers are physical, political and institutional, and social and cultural. Specifically, the city lacks enough physical space, political support, and the evaluation of travel behavior and demand. Also, some private stakeholders are reluctant to give up on-street car parking space for cycling lanes, and the negotiation process is difficult and time-consuming. To overcome these barriers, Hamburg requires cycling-oriented urban design, a strategic and integrated cycling action plan, strong political support, and target group-oriented communication.

Keywords: cycling; policy implementation; barrier; Hamburg

1. Introduction

Cycling is gaining increasing attention as a zero-emission, low-cost, and convenient mode of transport [1,2]. Compared with motorized transport, cycling can not only mitigate rush-hour traffic congestion [3], but also be less aggressive for children and older adults. Cycling, particularly the bike-sharing system, helps address the "last mile" issue and enlarge service areas of public transport [4]. Moreover, cycling can increase physical activity levels and improve physical and mental health [5–9]. Though there are risks of traffic accidents and exposure to pollution, researchers found that the health benefits of cycling would outweigh the risks [5,6].

Given the various benefits of cycling, an increasing number of cities around the world have committed to increasing cycling [10–12]. Some European cities—for instance, Copenhagen, Amsterdam, and Muenster—already have a high percentage of people cycling for transport. These cities have relatively long cycling cultures, well-developed pro-cycling policies and programs, as well as adequate cycling infrastructure [13].

In recent years, some big German cities have expended great efforts in promoting cycling, for example, cities like Berlin, Munich, and Hamburg [12,14]. However, cycling promotion in big cities in Germany is challenging. First, Germany has a high level of car ownership and a sufficient and high-quality road infrastructure supply that can facilitate convenient car use [15–17]. The passenger car is the major mode of commuting for employees (67.7% in 2016) [18]. When many people already use a car as part of their daily routine, it is possible that they are reluctant to change their travel behavior [19]. Second, the automotive industry is important to Germany both economically and politically. German economic lobby groups strongly support the automotive industry and motorized transport to ensure thriving development [16]. Therefore, the implementation of pro-cycling policies and measures may encounter various barriers.

Many studies have investigated barriers to cycling. Studies have found that potential barriers include: safety concern [20–22]; vandalism [20]; impracticality for daily use and perceived physical discomfort [23]; lack of cycling infrastructure [24]; and viewing cycling as a subcultural choice [25,26]. To help mitigate these perceived barriers and increase the public image of cycling, implementation of pro-cycling policies and the provision of a better cycling infrastructure are recommended [8,13,24]. However, not enough studies have focused on barriers to the actual implementation of pro-cycling policies.

To promote cycling more efficiently, planners need to better understand the characteristics of the barriers to policy implementation, the underlying reasons, and the possible solutions to address them. This study took an in-depth look at Hamburg. Hamburg is a city state and the second largest city in Germany with a population of over 1.8 million [27]. Hamburg has been a car-friendly city for the last few decades, and 68% of households have at least one car [28]. According to the 2016 "Bicycle Climate Test" survey, which is a nation-wide survey on cyclists' perception that is organized by the German Cyclist's Association (ADFC), Hamburg ranked 31 out of 39 German cities with a population over 200,000 [29]. This survey implies that many cyclists are unsatisfied with the cycling environment in Hamburg.

Promoting cycling as a mode of transport and improving the cycling environment are gaining increasing importance in Hamburg's agenda. Hamburg started a major cycling promotion in 2008, which was a few years later than other big German cities including Berlin, Munich, and Frankfurt [12]. With many actions being planned and implemented, Hamburg serves as a good example for exploring the challenges in transitioning from a car-dependent city towards a cycling-friendly city. The experience is helpful for other cities with similar goals. According to the study in Hamburg, this research aims at answering: (1) What are the barriers to implementing pro-cycling policies in Hamburg? (2) What are the underlying reasons for the barriers? Based on the findings, suggestions for overcoming the barriers are proposed.

2. Literature Review

2.1. Policies to Promote Cycling

Existing studies have summarized different types of interventions to promote cycling, such as infrastructure provision, policy and legal intervention, communication, marketing, community design, and a comprehensive policy package [2,30,31]. In many cities, improving the cycling infrastructure is the main task for pro-cycling policies. Different cycling infrastructure includes cycling lanes (separated from motor traffic by painted lines), cycling tracks and paths (physically separated from motor traffic), and various parking facilities [32,33]. Other than cycling lanes, tracks, and paths, German cities are innovative in establishing bicycle priority streets (Fahrradstrasse) where cyclists have priority on the entire street with minimal car traffic [14].

Notably, a comprehensive policy package was found to be highly effective in promoting cycling [2,13,30,34]. Some studies highlight the combination of pull and push measures [2,33,35]. Pull measures are policies to improve cycling infrastructure and services, provide incentives for bicycle use, and so forth. Push measures try to make car use more expensive and less convenient [2]. Some highlight the combination of hard and soft measures [12,36]. Hard measures focus on the structural change, for example, constructing cycling infrastructure. Soft measures focus on psychosocial aspects to achieve modal shifts, for example, a communication campaign [36,37]. Measures with different focuses can complement each other to achieve a higher efficiency in promoting cycling for transport [13].

2.2. Barriers to Implementing Sustainable Transport Policy

Barriers can be understood as obstacles that limit or even prevent policy implementation [38]. Many studies have investigated barriers to implementing sustainable transport policies [38–41]. In one of the studies, Banister [41] summarized six possible types of barriers: resource barriers, institutional and policy barriers, social and cultural barriers, legal barriers, side effects, and other (physical) barriers (see Table 1 for further description). According to a review of 61 policies, Banister [41] found that resource barriers, institutional and policy barriers, and social and cultural barriers occurred the most. May et al. [38] grouped barriers to transport policy implementation as legal and institutional, financial, political and cultural, and practical and technological. Legal, institutional, and technological barriers are highlighted as more difficult to overcome. Vigar [39] categorized barriers into four types: financial, organizational, cultural, and political. By examining the barriers to adopting sustainable transport planning approaches in the UK, Vigar [39] found that cultural and political barriers notably slow down the transition in transport demand management. In sum, these studies provided various frameworks for analyzing barriers to sustainable mobility transition and highlighted some important barriers. However, not enough research has focused specifically on barriers to cycling transition [10].

Table 1. Category of barriers to implementing sustainable transport policies.

Category of Barrier [1]	Description [1]	Cycling—Related Example
Resource	Problems in acquiring an adequate amount of financial and physical resources in time	Not enough investments [42]
Institutional and political	Problems in the cooperation between organizations and conflicts among different policies	Lack of leadership and political will [42]
Social and cultural	Problems in public acceptability of the measures	The public's resistance to construct or use certain types of cycling infrastructure
Legal	Measures can be restricted or even cancelled by laws and regulations	Cycling lane construction is not permitted on certain roads
Side effects	The effects on other activities	Increased traffic risks for cyclists
Other (physical)	Space or topography restriction	Lack of space for cycling lanes, unsuitable topography [41]

[1] The category and description of barriers are from [41].

2.3. Barriers to Implementing Pro-Cycling Policy

Cycling has been marginalized in many cities' modernized transport planning [43,44]. Several studies in the UK have examined the barriers to pro-cycling policy adoption and implementation and have highlighted the lack of funding and leadership [42,45,46]. Moreover, many European cities have a compact urban structure and scarce street space, in particular in inner city areas. It is challenging to implement cycling infrastructure in a restricted space [47]. In the German context, there is a higher national cycling modal share than the UK; however, a stronger influence of car lobby groups possibly exists [10]. It is possible that the major barriers are different across European cities.

Given various potential barriers to implementing pro-cycling policies, identifying the major barriers could help to design more targeted and context-specific measures [34]. To identify the barriers, experiences could be learned from general sustainable mobility studies. The barrier framework of Banister, as described above, is suitable for analyzing a wide range of sustainable mobility policies' implementation [41,42,48]. Since cycling is a typical approach towards sustainable mobility, this research employed this framework to explore the barriers to pro-cycling policy implementation in Hamburg.

3. Materials and Methods

This study took Hamburg as a case city. Data was collected through semi-structured expert interviews, document surveys, and was complemented by field observations. The rationale for adopting these methods was to get an in-depth and comprehensive understanding of the barriers faced by Hamburg in cycling promotion. Existing studies showed that both government and non-governmental organizations play roles in policy implementation [49,50]. In Hamburg, staffs from local authorities are the main implementers of pro-cycling policies. The authorities cooperate with several companies to deploy, construct, and maintain the cycling infrastructure [51]. Also, local authorities consult non-governmental organizations (NGOs) and a wide range of experts for better policy implementation. In this study, the selection of interviewees aimed to include experts that were closely related to cycling for transport in Hamburg. Therefore, experts were invited from local authorities, organizations that cooperated with authorities, and academics. Five interviewees, including both males and females, accepted the interview invitation. It was planned that two more transport planners would be interviewed; however, they declined. The collected information on the major barriers was consistent across all interviewees. The barriers mentioned by the fifth interviewee are repetitive without new information. Therefore, no new interviewees were recruited after the fifth interview.

Information about the five interviewees is listed in Table 2. For ensuring the anonymity, the interviewees were coded as H1–H5 in the results. All five interviewees were pro-cycling, and they were familiar with the cycling development and planning process in Hamburg. Moreover, they had expertise in different aspects, e.g., theory and practice on cycling planning and policy implementation, integration of bike and ride, and communication with a variety of stakeholders.

Table 2. Profile of interviewees in Hamburg.

Reference Code	Position	Organization
H1	Senior transport engineer and researcher	Hamburg University of Technology (*Technische Universität Hamburg*)
H2	Cycling planner	Ministry of Economy, Transport and Innovation (*Behörde für Wirtschaft*, *Verkehr und Innovation*)
H3	Senior transport planner	Ministry of Economy, Transport and Innovation (*Behörde für Wirtschaft*, *Verkehr und Innovation*)
H4	Staff and transport policy consultant	The German Cyclist's Association (*Allgemeine Deutsche Fahrrad-Club e. V.*) (*ADFC*)
H5	Staff for B + R (bike-and-ride)	The Hamburg Public Transport Association (*Hamburger Verkehrsverbund GmbH*) (*HVV*)

The interviews were guided by a list of semi-structured questions. First, the researcher asked background information about the interviewees, including their work experience, current work projects, and subsequent plans. Second, the interviewees were asked to express their opinions on the changes in the cycling environment, as well as opinions on key policies related to cycling in recent decades. Third, and most importantly, interviewees were asked about barriers (difficulties, challenges, and conflicts) to implementing pro-cycling policies. Subsequently, interviewees were asked to provide recommendations for policy implementation. When interviewing the expert (H5) from the Hamburg Public Transport Association, the researcher asked more detailed questions about B + R (bike-and-ride) programs. The interviews were conducted between June and September 2017. Four of the five interviews (H1, H2, H4, and H5) were recorded with permission and each lasted approximately 70 min.

The four recorded interviews were transcribed into text and were analyzed using a qualitative content analysis method developed by Schreier [52]. The transcripts were coded one by one, which was assisted by the software NVivo 11. The software helps to generate a node hierarchy (a coding framework) with clear references to the transcripts. The node hierarchy includes parent nodes (main categories) and child nodes (subcategories), where each parent node could contain one or more child nodes and the child node could contain further child nodes, forming a node hierarchy [53]. In the coding process, transcripts were read line by line and were summarized as nodes. Passages with the same topics were assigned to the same nodes and each assigned passage was coded as a reference under the node. The major parent nodes included "cycling trends and policies", "barriers to policy implementation", and "recommendations".

The coding of "barriers to policy implementation" used both concept-driven way and data-driven way [52]. The concept-driven way means that the main categories of barriers were adopted from the barrier framework that was developed by Banister [41]. The data-driven way helps to further generate subcategories of barriers by summarizing the related passages from interviews. Table A1 (in Appendix A) shows the main categories and subcategories of barriers, as well as examples of coding passages. The importance of each specific barrier was determined by the number of references of each subcategory (child node), which represents the frequency that they were mentioned by the interviewees.

A document survey was conducted to collect information on cycling trends and policies in Hamburg. The analyzed materials are listed in Table 3, for example, action plans and progress reports. Most documents are from official websites of the Free and Hanseatic City of Hamburg. Some documents were recommended by interviewees and local planners.

Table 3. Summary of analyzed documents.

Type	Document	Year	Source
Action plan	Cycling Action Plan for Hamburg	2007	[54]
Action plan	Alliance for Cycling	2016	[51]
Progress report	Cycling strategy for Hamburg: Progress report 2015	2015	[55]
Progress report	Hamburg—European Green Capital: 5 Years On.	2016	[56]
Development concept	B + R development concept for the Free and Hanseatic City of Hamburg	2015	[57]
Mobility program	Mobility program 2013—Basis for continuous transport development planning in Hamburg.	2013	[28]
Planner's presentation	Cycling in Hamburg	2017	from a local planner

In addition, field observations were conducted based on the locations that interviewees mentioned in the interviews. Cycling infrastructure and people's travel behaviors are observable, and observation helps to better understand local infrastructure for cyclists [58]. Photos taken by the author during the field observations were used to facilitate presenting the results.

4. Results

4.1. Cycling Trends and Policies in Hamburg

In recent decades, the number of people cycling in Hamburg has increased. The modal share of cycling was 7% in 1982, 9% in 2002, 12% in 2008, and 15% in 2017 [28,59].

To promote cycling, the Senate of the Federal State of Hamburg agreed on a "Cycling Action Plan" in 2007. It included seven key fields of action: cycling paths, parking, bike and ride, security, public relations/communications, tourism, and services [54]. The plan aimed to double the modal share of cycling from 9% in 2002 to 18% in 2015 [12,54]. Hamburg has had a cycling coordinator since 2015 to act as the public face of cycling in the city and to coordinate activities across authorities to promote cycling.

In June 2016, representatives of the Senate, the borough offices and councils, and the mayor of Hamburg signed an agreement called "Alliance for Cycling" (Bündnis für den Radverkehr), which aims to develop Hamburg into a cycling-friendly city and to increase the modal share of cycling to

25% by the 2020s [51]. In this agreement, there are three main action fields: *infrastructure*, *service*, and *communication*.

The most important action field is *infrastructure*. The priority in infrastructure is to construct and refurbish the Veloroute network, which is the citywide cycling network in Hamburg. The concept of the Veloroute network was developed in the late 1990s, encompassing 14 Veloroutes with a total length of approximately 280 km and aiming to connect the suburban area and city center [51,55]. Only 80 km of the 280 km network has been completed, and the remaining 200 km is planned to be finished by 2020 [51]. To consolidate the Veloroutes, the city is also constructing cycle parking facilities, leisure cycling routes, and cycling paths at the suburban and district levels [51].

Regarding *service*, the main focuses include cleaning of cycling paths and winter surface clearance, planning and implementing B + R facilities, and developing the public bicycle hiring system. Surface clearance is particularly important in autumn and winter to ensure the safety and usability of cycling paths. In recent years, Hamburg has introduced high-quality B + R facilities, which include two-story parking racks, parking boxes with locks, and storage boxes for cyclists' equipment (Figure 1). The city plans to deploy about 28,000 B + R parking places by 2025 [51,57]. For long-distance railway stations, there will be an increased number of cycle stations and enclosed parking garages. The public bicycle hiring system of Hamburg, StadtRAD (Figure 2) was established in 2009. In 2016, there were about 2500 bicycles at 206 docking stations, with over 402,000 users [56]. Now it is one of the most successful bicycle hiring systems in Germany and Europe [56].

Figure 1. Bicycle parking facilities near public transport stations. (Photos by author.)

Figure 2. StadtRAD, the public bicycle hiring system in Hamburg. (Photos by author.)

Communication is an essential tool in encouraging people to use bicycles. Hamburg plans to have a significant cycling campaign in 2018. The campaign will not only provide general support, such as education and instructions to facilitate safe and enjoyable cycling, but it will also focus on groups of people who do not favor cycling or have biased attitudes towards cycling. For better cycling conditions, Hamburg already has an internet platform called "Melde-Michel" on which citizens can report deficiencies in the current road infrastructure so that the related governmental administrations can be informed and can deal with the deficiencies [51].

4.2. Barriers to Implementing Pro-Cycling Policies in Hamburg

This section presents the barriers to implementing pro-cycling policies that emerged from expert interviews. Each barrier and the frequency that it was mentioned by interviewees are summarized in Table 4. Based on the barrier framework from Banister [41], the most frequently mentioned categories of barriers are "physical barriers", "political and institutional barriers", and "social and cultural barriers". The frequently mentioned barriers were consistent across different interviewees. Since no content fits into the category "side effects", this category is not included in the following sections.

Table 4. Summary of barriers to implementing pro-cycling policies in Hamburg.

Category of Barriers	Number of Times Mentioned
Physical	
Lack of space	12
Political and institutional	
Lack of political support	10
Lack of evaluation of travel behavior and demand	6
Time-consuming negotiation with private stakeholders on road space redistribution	4
Lack of long-term and integrated planning	3
Landscape conflicts between cycling infrastructure and local landscape	3
Social and cultural	
People's reluctance to give up on-street car parking space	4
People's reluctance to use on-road cycling lanes	3
Resource	
Lack of engineers	3
Legal	
Not permitted to build new bridges for cyclists	1

4.2.1. Physical Barriers

The lack of space for cycling infrastructure was the most frequently mentioned barrier (n = 12) and was mentioned by all interviewees (Figure 3). Most existing cycling paths are narrowly located alongside sidewalks and cannot meet current standards and needs (Figure 4). This is partly due to historical reasoning as cycling paths were built in a car-friendly time using an old standard. As explained by one interviewee:

> *"So all the area as it is now—the split up between pedestrian, parking cars and bicycle—[are] from 1970s and 1980s, that means the time when Hamburg has the main goal to be a car-friendly city. [. . .] They [the cycling lanes] are very very small, about 80 cm to 1 m. Of course there are very much conflicts with pedestrians."*
>
> [H2 Cycling planner]

Figure 3. The lack of cycling lanes. (Photos by author.)

However, planners nowadays have difficulty in constructing and refurbishing the cycling infrastructure when most areas of the city are already built up. The street space is scarce, particularly in the inner-city areas with dense population. The interviewees mentioned street trees and on-street car parking (Figure 5) which hinder the broadening of cycling lanes and the addition of cycle parking facilities.

"There are lots of cars parking there and also there are illegal parking. [. . .] To modernize this road, many of this illegal parking had to gone. People are buying more and more cars, statistics shows they don't drive these cars they buy, and of course they want to put them in front of their house."

[H2 Cycling planner]

Figure 4. Cycling lanes located alongside the sidewalks. (Photos by author.)

Figure 5. On-street car parking. (Photos by author.)

4.2.2. Political and Institutional Barriers

Lack of political support was the second most frequently mentioned barrier (n = 10). Not all the political parties have a proactive attitude towards promoting cycling, and different districts have different political majorities. Interviewees agreed that the political commitment to promote cycling is improving. However, the overall transport policies are still in favor of motor traffic in Hamburg.

"To be fair to the politicians, in general cycling is a good thing, and as soon as you get conflict of interests with motorized traffic or even with the public transport, then cycling does tend to fall aside quite quickly. [. . .] As an example, when there was debate about having citywide 30 km/h rules with the exception in certain places and some of the main roads, they said that Hamburg economy will come to a standstill. [. . .] So cycling has been moved up to the agenda but I would not say it's a priority in Hamburg, definitely not."

[H1 Researcher]

It is widely considered that the harbor is the economic backbone of the city. To boost the economy, freight transport is crucial from the perspective of politicians and economic lobby groups. However, the challenge is that cyclists have to use the same roads with heavy freight traffic. Many cyclists are afraid of the giant trucks due to possible blind spots and dangerous accidents.

> *"The port and the logistic lobby is very strong in Hamburg. And partly because of the problem of non-existence ring road, I mean we have Ring 1 and Ring 2, [. . .] but we don't have a sort of ring road in terms of a motorway where you could bypass Hamburg. If you go from east to west, you have to go through the city. [. . .]. And then of course a lot of the port traffic, the lorries also have to travel across the city. [. . .] This is an additional, in some cases an obstacle from the point of view of cycling."*
>
> [H1 Researcher]

In addition to the lack of political support, it is difficult to deal with private stakeholders' disagreements on road space redistribution (*n* = 4). The cycling lanes that are situated next to private buildings need careful and time-consuming negotiation among stakeholders to reach an agreement on a plan.

> *"They [the citizens] want to participate more in the administration. [. . .] They want to influence the road. [. . .] Whether the tree in front of their house they want to keep, or whether there are parking spaces which they believed to be their own parking space in front of their house, and so on, so this is very complex."*
>
> [H2 Cycling planner]

It is a challenge to implement such plans not only outside private buildings, but also in public spaces due to landscape conflicts (*n* = 3). For example, there are debates over whether installing cycle parking infrastructure outside some historical buildings would block or destroy the historical landscape.

Furthermore, several barriers are related to the cycling strategy. First, there is a lack of regular travel behavior surveys (*n* = 6). When the cycling strategy "Alliance for Cycling" set a new aim in 2016 (to increase the modal share of cycling to 25% by the 2020s), it remained unclear whether the previous aim set in 2007 (to increase the modal share of cycling to 18% in 2015) was accomplished or not. Due to the lack of a baseline for evaluation, some newly deployed infrastructure may not fully meet the demand. One interviewee provided an example:

> *"You shouldn't start too small. [. . .] The [parking facilities around] Saarlandstrasse [Station] is already full after a few days or weeks, if you have good conditions, people's use may be exploding. I think sometimes Hamburg is also very careful, too careful, with the number. [. . .] And I think they also underestimated that people are willing to ride a very long distance with their bikes; that is also important."*
>
> [H5 B + R planner]

In addition, several interviewees stated that there is a lack of consideration for a long-term and integrated plan for cycling (*n* = 3). So far, it is hard to get a full picture of the overall transport planning strategy.

> *"We have strategy for cycling but we have no official strategy yet for any of the other modes. It's a little bit difficult you have sort of things moving one way on the one side and the other moves the other way on the other side, and there is no strategic overlap and overview of where you want to go."*
>
> [H1 Researcher]

4.2.3. Social and Cultural Barriers

Social and cultural barriers are related to public acceptability of policy measures. In Hamburg, the primary social and cultural barrier is that some people are reluctant to give up the on-street car parking space to add new cycling infrastructure (n = 4). Many people are used to travelling by car, and some shop owners believe that their customers would like to travel by car.

> "*They [Shop owners] are afraid if we take the car parking space away and put places for bike, they think they would get bankrupt, nobody would buy anything from them.*"
>
> [H2 Cycling planner]

> "*And some cyclists are also motorists and they say 'no, I wouldn't want to give up my parking space'.*"
>
> [H4 NGO]

Another barrier related to the public acceptability is that many people are afraid to use the newly built on-road cycling lanes (n = 3) (Figure 6). One interviewee (H2) stated that it is safer to use on-road lanes because at intersections, the drivers can see that some cyclists are going to turn left or right more clearly, rather than the cyclists suddenly appearing at intersections. However, many cyclists do not like to use the new lanes and they prefer to ride in a pedestrian area despite increasing conflict with pedestrians.

Figure 6. On-road cycling lanes. (Photos by author.)

4.2.4. Resource Barriers

In general, interviewees did not consider financial resources as a barrier; however, two of them (H2 and H5) mentioned the lack of engineers (n = 3). One interviewee (H2) saw this as an important barrier that slows down the process.

> "*I don't think money is the problem, but we don't have enough engineers to do the planning work. [. . .] We need more engineers. Road building companies don't have as much engineers as we need to rebuild all the roads we want. So it takes some time.*"
>
> [H2 Cycling planner]

4.2.5. Legal Barriers

The only noted legal barrier was that at present, building new bridges for cyclists is not permitted (n = 1). Hamburg has about 2500 bridges. However, the traffic flow on some bridges is very high during peak hours. Cyclists have to ride through the busy bridges with massive amounts of motor traffic. Due to the existence of a large number of bridges, some of which need extensive maintenance because of lots of freight transport, it is hard for the city to build new bridges for cyclists. Therefore, it is difficult to develop a cycling network that is as connected as the motor traffic network.

4.3. Individual Level Barriers to Cycling

Although the major interview question was regarding the barriers to policy implementation, some individual level barriers emerged as well. First, some people believe cycling is not a mainstream mode of transport. They think that cycling is not safe or is used more for leisure purposes (H2). Second, for some people, cycling is impractical. It is more convenient to commute by car, especially for those who live far away from the city center (H4). Third, some new residents might not prefer to cycle. People from different countries may have experienced different mobility cultures and have different travel behaviors (H2).

5. Discussion

5.1. Summary of Findings

In summary, this research found that the frequently mentioned barriers are a lack of space (n = 12), lack of political support (n = 10), lack of evaluation of travel behavior and demand (n = 6), time-consuming negotiation with private stakeholders on road space redistribution (n = 4), and people's reluctance to give up on-street car parking space (n = 4).

The lack of space is highly important in implementing pro-cycling policies in Hamburg. This is different from implementing other sustainable transport policies that have no space requirement (e.g., traffic calming and adopting alternative fuels and vehicles). For historical reasons, most cycling lanes were created by taking space from sidewalks decades ago, and the city has been dominated by cars in recent decades. However, it is critical to redistribute space for cycling for sustainable and equitable mobility [60].

To redistribute the space for cycling, strong political support is essential. Although the political support for cycling in Hamburg has improved in recent years, the political courage is still not enough to take more push actions to restrict car use and facilitate cycling. In Hamburg, the transport department belongs to the Ministry of Economy, Transport and Innovation. Since the economy department and the transport department are in the same ministry, it is possible that the interests are shifted more toward the development of the economy (H1). The lack of political support was in line with existing studies on cycling and general sustainable mobility [42,61]. Politicians welcome the term "sustainable" in planning concepts; however, it is hard for practitioners to realize it in planning practice [39,40].

Case studies in England underlined the barrier of a lack of funding [42,45]. This barrier is of less importance in the Hamburg case. However, it is in accordance with British findings that the adoption and implementation of pro-cycling policies could be influenced by various stakeholders [42,45], for example, car lobby groups, shop owners, and residents. The influence of car lobby groups on transport policy echoes a case study in Freiburg where car lobby groups tend to be against the speed and emission limits [17]. The individual level barriers that emerged (safety concern, impractical, and subcultural for commuting) were in accordance with a number of studies [20–23,25].

It is obvious that some barriers are interrelated. When decision-makers are not fully committed to improving the cycling environment, practitioners can hardly acquire sufficient space, budget, and human resources [42]. The lack of evaluation of travel behavior and demand might also be due to a lack of human resources. Furthermore, time-consuming negotiation with private stakeholders on road space redistribution is closely related to people's reluctance to give up on-street car parking space. Although individual level barriers do not affect the implementation process directly, they may reinforce social and cultural barriers.

5.2. Suggestions for Overcoming Barriers

5.2.1. Cycling-Oriented Urban Design

Existing studies highlight the importance of cycling-oriented urban design, underlining that planners need to think more about cyclists' perceptions and experiences [62]. In Hamburg, the priority of road space distribution favors motorized transport over cycling when street space is limited. To overcome the physical barrier, fundamental change of the road space is necessary, for example, removing on-street car parking, reducing motorized traffic lanes, and banning cars where streets are extremely narrow.

Reducing the space for car use may be met with resistance from private stakeholders. Lessons may also be learned from Oslo where a step-by-step measure was taken to ban car parking in the city center. For example, by establishing several pilot areas, the shop-owners (outside the pilot areas) could see the change of the flow of customers before and after the reuse of car parking areas [63]. Having opportunities for experimental measures is helpful to implement new measures [33].

Cycling-oriented urban design could also help overcome people's reluctance to use on-road cycling lanes by enhancing the visibility of cycling infrastructure to increase perceived safety [62,64,65]. From a cyclist's perspective, the same cycling infrastructure is not suitable for cyclists with a different level of skills [62]. In Hamburg, the street space might not be enough to add green belts protection for on-street cycling lanes. However, some informal separation could be added, for example, using a small strip of cobbles to separate the motorized traffic lanes [65] and coloring of the on-street cycling lanes to form a distinct demarcation [62]. These types of separation should also be complemented by a reduction of motor traffic speed, which could increase people's reaction time and increase perceived safety [66].

One more urban design solution is to combine the cycling planning with landscape planning and design. Street trees have been considered as one factor that leads to space scarcity for cycling. For cycling-oriented urban design, a full use of existing trees should be made to increase the amenities and comforts of cycling routes. In some areas with historical buildings, bicycle parking facilities should be designed to better adapt to the local historical landscape. Attractive designs can also encourage cycling use (H5).

5.2.2. Strategic and Integrated Planning for Cycling

Planners have to deal with various conflicts of interest in developing a sustainable city. A strategic and integrated cycling action plan should be able to mitigate the conflict of interests and design practical and innovative solutions [19]. To achieve these abilities, a strong planning system with high-skilled planners is critical [67,68]. Studies in Copenhagen highlight that successful cycling infrastructure planning needs a group of experts with various expertise [11]. With the development of spatial data science, more advanced planning tools should be brought to cycling network planning, for example, spatial analysis, modelling [69], and big data [70]. Training of planners and practitioners could help to refine the planning works [68].

Cycling should be integrated with other modes of transport to create a multi-modal network ([47]; also suggested by H1) and should further be integrated with wider urban plans and policies [19]. Exploring the full potential of cycling in the overall transport system and urban planning could help increase transport efficiency and could even increase financial resources for cycling [47]. For big cities like Hamburg, the B + R integration is essential. A high-quality B + R service with more programs to advertise the services could be helpful (H5).

Moreover, regular travel behavior surveys and spatial analysis are essential for measuring and adjusting the implementation progress. Cycling use in Hamburg continues to increase; it is necessary to have a more accurate estimate of the demands before planning and deploying new cycle parking facilities at different locations. The cycling use might boom with the adequate provision of cycling infrastructure (H5).

5.2.3. Strong Political Support

To ensure the implementation of pro-cycling policies, a strong political commitment has been considered of high importance by all the interviewees and many researchers [33,42,45]. In Hamburg, political courage and cross-party political support should be enhanced to facilitate long-term and consistent planning and implementation. As suggested by one interviewee (H1), politicians should make more concrete and measurable political goals and should allow for greater visibility of cycling infrastructure. Regarding current pro-cycling policies, most are pull measures, for example, providing high quality parking infrastructure where space permits. It would be more efficient if pull measures were complemented by more push measures to restrict car use.

5.2.4. Communication

Efforts to overcome barriers could also be made by communication, in particular to overcome social and cultural barriers. It is necessary to have targeted group-oriented communication with training and educational programs according to the type of (potential) cyclists (e.g., novice cyclists, new residents, older adults, car drivers) [19,71]. Communication with private stakeholders is critical in achieving agreement on road space redistribution. The planners in Hamburg emphasized the importance of on-road cycling lanes that could make cyclists more visible to drivers. Knowledge on the advantages of on-road cycling lanes over off-road cycling lanes should be explained with empirical evidence, and education on how to use the on-road cycling lanes should also be provided.

5.3. Limitations

This research has several limitations. First, although frequency (number of times mentioned) is used to evaluate the importance of different barriers, the frequency should be treated with caution because only five interviews were conducted. This means that the frequency in this study can only decide which several types of barriers are more important and is not able to decide which barrier is the most important one. Although the major barriers are consistent across interviewees, it would be better if more interviews could be conducted, for example, more interviews with people from different political parties and urban planning authorities. There is also a potential for subconscious bias in interviews. The interviewees' opinions might not be able to fully represent the organizations.

Second, the interviewees mentioned some residents' opinions on reallocating road space for cycling. For example, one interviewee (H4) noted that some people are reluctant to give up their car parking space. The author finds it difficult to quantify the percentage of residents sharing the same opinion due to a lack of data. It would be better to have more data on local residents' attitudes to clarify how difficult it is to manage barriers related to local residents.

6. Conclusions

For effective pro-cycling policy implementation, identifying major barriers and removing them is critical. This study identified different types of barriers according to in-depth interviews with cycling experts in Hamburg. By using the barrier framework of Banister [41], this research found that the major barriers are physical, political and institutional, and social and cultural. Specifically, the city lacks enough physical space, political support, and evaluation of travel behavior and demand. Also, some private stakeholders are reluctant to give up on-street car parking space for cycling lanes, and the negotiation process is difficult and time-consuming.

Some barriers are more manageable, for example, it is feasible to enhance the evaluation of travel behavior and demand for a more accurate plan. Some barriers are more entrenched, for example, it is not easy to gain strong political support for cycling when facing the embedded car culture. To overcome the barriers, Hamburg needs multifaceted and integrated approaches, specifically, cycling-oriented urban design, a strategic and integrated cycling action plan, strong political support, and target group-oriented communication.

It should also be noted that several measures to promote cycling in Hamburg can be learned by other cities, for instance, an "Alliance for Cycling" to reach a basic consensus and commitment; a bicycle coordinator who can oversee the whole implementation procedure and ensure a sense of leadership for cyclists; high quality parking infrastructure where space allows; and public participation. These measures can be helpful for cities where cycling planning is still in its infancy.

For future studies, follow-up research is necessary to examine the implementation process and the effectiveness of different interventions in Hamburg. More research is necessary to refine the measures to gain stronger political support, for example, using cost-benefit analysis and conflict analysis. It is possible that the major barriers to promoting cycling differ from city to city. Therefore, more research on barriers that appear in cities at different stages of development is necessary. Planners can promote cycling more efficiently with a better understanding of potential barriers.

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Appendix

Table A1. List of coding categories of barriers and examples of coding passages.

Category of Barriers	Subcategory of Barriers	Example of Coding Passages
Physical	Lack of space	*"This city is finished, that means we have no free spaces available to use for bike transport, we have to take some of the area which is now used for something else."* [H2] *"We don't have place, we always have houses next to the roads and we have a lot of trees next to the roads."* [H4] *"In Dammtor [Station] it is really difficult because there is no space anywhere, there are so many bikes because the university is close to it, and it is so important to improve the facilities."* [H5]
Political and institutional	Lack of political support	*"The economic cars the trucks. [. . .] The politicians always say 'we can't stop it, it's important for Hamburg.' [. . .] Many points [when] there are not enough space, always the cars are the winners, but not the bikes." [H4]* *"At the moment, the competition is not fair, because the privilege of car is not accessible to the bike."* [H2]
	Lack of evaluation of travel behavior and demand	*"Actually, if everything that is written in there is actually implemented, it would be great. But the problem is they haven't assigned definite resources on a year-by-year basis. [. . .] If you say you are going towards some kind of goal but you didn't measure where you are, obviously it's difficult to say whether you have actually made some progress."* [H1]
	Time-consuming negotiation with private stakeholders on road space redistribution	*"Every road is special so you have to discuss every road, it is a hard process and it takes a long time to think how we can do it here. Sometimes there is also a problem, the first part of the road we have one solution for bikes and it changed for the next part, [. . .] and that for both cars and bicycles is difficult."* [H4]
	Lack of long-term and integrated planning	*"We always say you have to think about the plan; you have to think about the cycling for the next ten years, or 15 years."* [H4]
	Landscape conflicts between cycling infrastructure and local landscape	*"Some stations are very old, there are monument conservation. [. . .] Because many people would like to leave their bikes under roofs to keep it dry, and especially these roofs at the main station, the city planning authority does not want any roofs around there, [. . .] they want to protect the view of the old buildings."* [H5]

Table A1. *Cont.*

Category of Barriers	Subcategory of Barriers	Example of Coding Passages
Social and cultural	People's reluctance to give up on-street car parking space	*"There are also some people who are very critical to this new idea of ride a bike. [. . .] Some people are afraid that someone would take their privilege of using cars away. [. . .] So they try to stop it and they don't like bikes to win the city and to get more space on the roads"* [H2]
	People's reluctance to use on-road cycling lanes	*"The people in Hamburg are used to use this very small bicycle ways next to the pedestrian. [. . .] The cyclists are afraid to ride near the car traffic. So they don't like this new bike lane. [. . .] This is a challenge as well to convince these people who are afraid of using the modern infrastructure."* [H2]
Resource	Lack of engineers	*"[. . .] they can't realize the concept for all the stations at the same time because there are too less people"* [H5]
Legal	Not permitted to build new bridges for cyclists	*"We want to improve the quality [of cycling infrastructure] and we don't want to drive [ride] with trucks on the same road. [. . .] So we need to increase the bridge or to add a new part for pedestrian and the bike traffic, it's always said no, it's not possible because our rule is no new bridges for no one and at no circumstances."* [H2]

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4. Planning for cycling in a growing megacity: Exploring practicing planners' perceptions and shared values (Paper III)[1]

Abstract

Cycling has long been marginalized in Chinese modern transport planning. With increasing attention being paid to cycling in recent years, it is important to have a better understanding of how local planners make practical judgments for cycling and the underlying considerations. This study examines practicing planners' perceptions and shared values of bicycle planning in Wuhan, a growing Chinese city. An exploratory sequential study design was employed by combining in-depth interviews and a questionnaire survey. A theoretical framework, the culturized planning model, was applied to guide the exploration of the planners' perceptions and shared values. The results indicate that planners generally have a positive attitude towards cycling, particularly regarding environmental and health benefits. They think a suitable role of cycling in commuting is to solve the first and last mile problem by complementing public transport, rather than cycling alone. Most planners are not satisfied with existing cycling conditions; however, they can only improve the cycling infrastructure selectively in a project-oriented way. A variety of challenges of improving the cycling condition are identified. In the changing and growing context, informal rules often play a role in planners' judgment-making.

Keyword: bicycle planning; planning culture; growing cities; Wuhan

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4.1 Introduction

In recent years, given the severe traffic congestion and air pollution in large Chinese cities, promoting cycling for transport is widely considered a promising way towards sustainable mobility (Z. Li, Wang, Yang, & Ding, 2017; M. Yang & Zacharias, 2016; Zhao, Nielsen, Olafsson, Carstensen, & Meng, 2018). Unlike in many European countries, the promotion of cycling in China focuses on encouraging public bicycle use rather than private bicycle use (J. Yang, Chen, Zhou, & Wang, 2015). Since 2016, there has been a rapid development in dockless bike-sharing (DBS) services. The sufficient bike provision and convenient usage attract large numbers of users, making DBS a promising way to increase the level of cycling (Y. Zhang, Lin, & Mi, 2019). Although DBS has significantly improved the flexibility of using a public bike, the limited cycling infrastructure in Chinese cities cannot provide cyclists with a safe and comfortable environment (Shi, Si, Wu, Su, & Lan, 2018).

In many large Asian cities, cycling does not have a clear or legitimate role in the transport system (Bakker et al., 2018; Zhao, Carstensen, Nielsen, & Olafsson, 2018). Cycling has long been marginalized in many Chinese cities' modernized transport planning. Because the main planning practices have focused on developing motorized transport in recent decades, many cities lack experience in planning for cycling (Frame, Ardila-Gomez, & Chen, 2017; J. Yang et al., 2015; Zhao, Carstensen, et al., 2018). It is challenging to promote cycling in rapidly growing cities facing the pressure of economic growth and development (Brussel & Zuidgeest, 2012; Mrkajić & Anguelovski, 2016). Although cycling is gaining increasing attention in growing cities, there is a lack of understanding of the relationship between the growing city and bicycle planning practice (Mrkajić & Anguelovski, 2016), as well as of how bicycle planning is embedded in the local culture (Brussel & Zuidgeest, 2012; Zhao, Carstensen, et al., 2018).

To improve our understanding of bicycle planning practices in growing cities, this study pays attention to practicing planners. Practicing planners play a critical role in improving cycling conditions, for example, by designing bicycle networks, installing cycle parking facilities, and integrating cycling into wider transport and urban plans (Deffner & Hefter, 2015; Zhao et al., 2018a). When planners design their strategies, their decisions and practical judgments are not only influenced by individual knowledge and expertise but also by their collective shared values and underlying societal values (Knieling & Othengrafen, 2015; Othengrafen, 2014; Othengrafen and Reimer, 2013). Their decisions and judgments are situated in local traditions, institutional frameworks, and political and economic contexts, reflecting planners' individual perceptions and a culture of practice (Fürst, 2009; Othengrafen, 2014). In spatial planning, it is important to understand unconscious perceptions and beliefs alongside professional and scientific values (Gazzola & Onyango, 2018).

Therefore, exploring practicing planners' perceptions and shared values of bicycle transport is helpful for improving our understanding of bicycle planning in growing cities. This study focuses on practicing planners in Wuhan, a typical growing city in China. Specifically, this study aims to investigate: how do planners view cycling for transport in a growing megacity? What are the major challenges of improving cycling conditions? How do planners make practical judgments for deploying cycling infrastructure and what are their underlying perceptions and values? To answer these questions, this study employs a mixed study design by combining in-depth interviews and a questionnaire survey.

4.2 Methodology

4.2.1 Study area

With over ten million inhabitants, Wuhan is the largest city in the central part of China. The city of Wuhan consists of seven center districts (888 km2) and six suburban and rural districts (7606 km2). The center districts are divided by the Yangtze River and the Han River, which can lead to a long travel distances if citizens need to cross the rivers. The terrain is generally flat and suitable for cycling. Similar to many other large Chinese cities, Wuhan has also experienced rapid motorization and decreased cycling. The modal share of cycling decreased from 35% in 1987 to 18% in 2016 (Gu, Kim, & Currie, 2019; L. Li, Chen, & Sun, 2009). Bike ownership decreased from 59% in 1982 to 29% in 2008 (L. Zhang, Zhang, Duan, & Bryde, 2015). DBS was introduced to Wuhan in December 2016, attracting an increasing number of people back to cycling. The total number of dockless bikes from different operators was approximately 700,000 in August 2017. The users of DBS are mostly young adults, around 75% of whom are 20−40 years old (WTDSRT & Mobike, 2017). Following the bus and metro, DBS now serves as the third major mode of transport in Wuhan (WTDSRT & Mobike, 2018).

Wuhan is a typical rapidly growing city. Unlike Shanghai and Beijing, which have already established a basic rapid transit system, most large cities in China are similar to Wuhan, which is still building the rapid transit system (e.g., the Wuhan Metro) on a large scale. The total length of the Wuhan Metro increased from 72 km at the end of 2013 to 305 km at the end of 2018 (*Changjiang Daily*, 2018; China Association of Metros, 2014), targeting a length of 606 km by the end of 2024 (National Development and Reform Commission, 2018). Wuhan serves as a representative case for investigating bicycle planning practices in many growing cities in China and the rest of the world, which are experiencing an increased awareness of planning for cycling and are also facing huge development pressure.

4.2.2 Theoretical framework

To achieve a comprehensive understanding of the interactions between the planning system and the cultural context, many researchers adopt and analyze the concept of planning culture, e.g., Keller et al. (1996), Othengrafen and Reimer (2013), Taylor (2013), and Wang (2013). Planning culture can be understood as “a cultural system that develops in the interplay of cultural codes, institutional settings, cognitive frames of the involved actors and the interactions between actors” (Othengrafen, 2014, p. 4). Based on this definition, researchers have developed a culturized planning model for understanding spatial planning in a situated and contextualized manner; this model includes three levels: planning artifacts, planning environment, and societal environment (see Figure 4.1 (a)) (Knieling & Othengrafen, 2015; Othengrafen, 2014; Othengrafen & Reimer, 2013). These three levels are interrelated, serving not only as organizational categories to systematically understand diverse elements in planning practice, but also as practical tools used to interpret how underlying values and taken-for-granted beliefs influence or control planning practices (Othengrafen & Reimer, 2013).

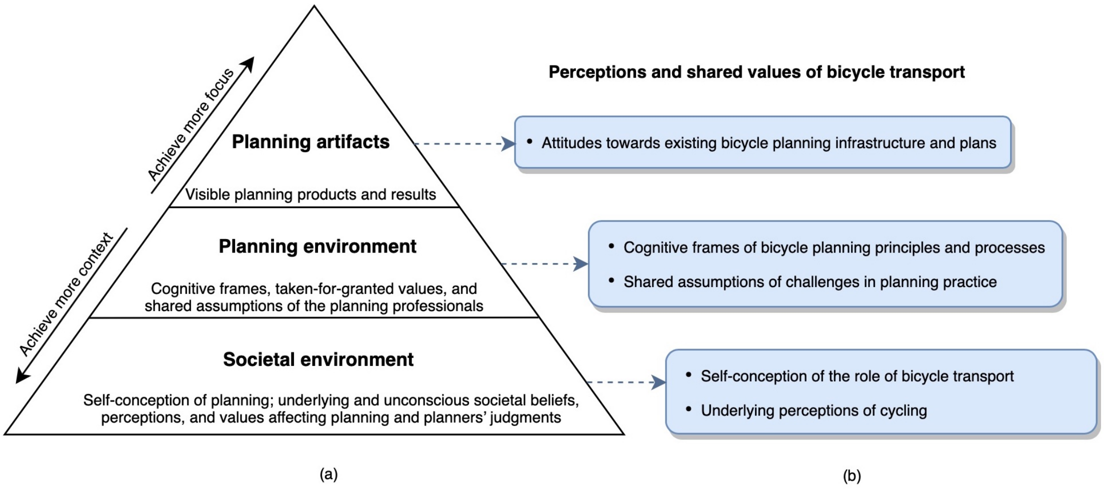

Figure 4.1. Theoretical framework for exploring perceptions and shared values of bicycle transport. (a) The culturized planning model (Othengrafen & Reimer, 2013); (b) Potential types of perceptions and shared values of bicycle planning based on the culturized planning model.

The culturized planning model provides researchers with a conceptual framework to analyze spatial planning practice in a contextualized manner (Othengrafen, 2014). Previous studies have successfully used this model for understanding different sections or levels of spatial planning, for example, bicycle planning (Zhao, Carstensen, et al., 2018), marine spatial planning (Gazzola & Onyango, 2018), and riverscape planning (Levin-Keitel, 2016).

In this study, the phrase "perceptions and shared values" represents a combination of planners' attitudes, perceptions, values, assumptions, and cognitive frames regarding bicycle planning. Potential types of perceptions and shared values of bicycle planning based on the culturized planning model are presented in Figure 1 (b). Different from the work of Zhao et al. (2018a), which explored the bicycle planning environment by examining the application of predefined generic bicycle planning principles (i.e., the Dutch CROW principles), this study investigated local planners' actual guiding norms and values when making plans and judgments. This helps to explore the non-manifested and informal bases of planners' judgments.

4.2.3 Data collection and analysis

This study employs an exploratory sequential study design which includes both qualitative and quantitative data collection and analysis. A mixed study design helps provide a deeper understanding of the research topic because qualitative results provide in-depth individual perspectives and quantitative results reveal trends and relationships (Creswell, 2014). The mixed study design includes three phases: semi-structured interviews, qualitative content analysis and questionnaire design, and questionnaire survey and analysis (Figure 4.2). The presentation of the results integrates both qualitative and quantitative analysis.

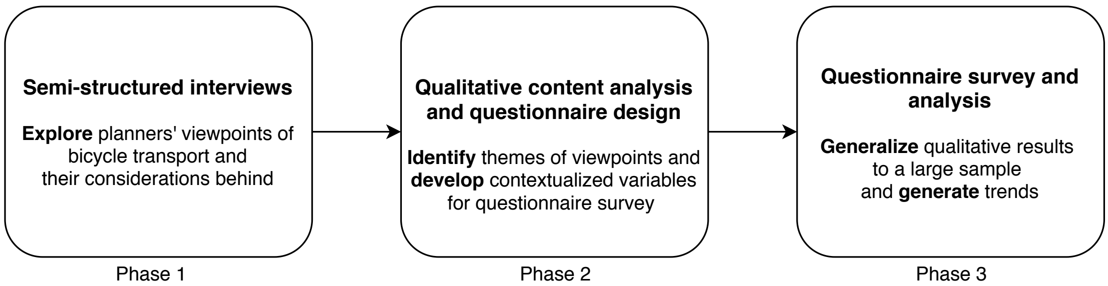

Figure 4.2. Study design.

For the first phase, semi-structured interviews were conducted to explore planners' attitudes, norms, and values concerning cycling and bicycle planning in Wuhan. Interviews with local planners are frequently used to help researchers acquire a comprehensive understanding of local bicycle transport development, planning processes, and planners' considerations (Koglin, 2015; Zhao, Carstensen, et al., 2018). A list of open-ended questions (see Appendix B) was developed following the five bullet points in Figure 4.1 (b) and guided by the culturized planning model (Othengrafen & Reimer, 2013).

Experts who works in a field related to bicycle transport in Wuhan were invited to be interviewed. After finishing each interview, the experts were asked to recommend other potential interviewees. Finally, ten interviews with experts from eight organizations were conducted. The ten interviewees included planners who are most closely related to bicycle planning in Wuhan (e.g., the planner who made the city-wide bicycle plan). Since no new information emerged from the tenth interview, no new interviewees were recruited. The ten interviewees' profiles are specified in Table 4.1. To ensure anonymity, they are coded as W1−10. Five in-person interviews (W1−5) were conducted in August 2017 and five telephone interviews (W6−10) were conducted between October and November 2018.

Table 4.1. Profile of interviewees in Wuhan

Code	Organization	Position
W1	Wuhan Transportation Research Institute	Senior traffic engineer
W2	Wuhan City Transportation Committee	Official (previous transport planner)
W3	Wuhan Planning and Design Institute	Senior urban and transport planner
W4	Wuhan Land Resources and Planning Bureau	Senior urban and transport planner
W5*	Beijing Mobike Technology Co., Ltd (Wuhan branch)	Public relations manager
W6	Wuhan Transportation Development Strategy Research Institute	Transport planner
W7	Wuhan Planning and Design Co., Ltd	Transport planner
W8	Wuhan Planning and Design Co., Ltd	Transport planner
W9	Wuhan Municipal Engineering Design and Research Institute Co., Ltd.	Transport planner
W10	Wuhan Planning and Design Co., Ltd	Senior urban and transport planner

* W5 is the only interviewee not from a planning organization. As a member of a DBS operator, W5 has experience cooperating with city planning and management authorities in managing dockless bikes and improving the cycling infrastructure.

The second phase was to analyze the interviews and design a questionnaire based on the results. All ten interviews were recorded with permission and were transcribed verbatim. Transcripts were analyzed using qualitative content analysis (Schreier, 2012) assisted by the software NVivo 11, which generates a coding framework with clear references to the transcripts (Bergin, 2011). Guided by the culturized planning model, the coding framework includes three mains categories: planning artifacts, planning environment, and societal environment (Othengrafen & Reimer, 2013). The planning environment category includes three subcategories: planning principles, shared assumptions of challenges, and shared values and informal rules in the planning process. The societal environment category includes the role of bicycle transport and perceptions of bicycle transport. To facilitate the presentation of results, direct quotations from interviewees and photos taken by the author were used. The direct quotations were translated by the author from Chinese to English.

The third phase was the questionnaire survey and analysis. The questionnaire survey identifies to what extent the viewpoints of the interviewees are held by wider practicing planners in Wuhan. The planners targeted here are not limited to transport planners; rather, they include any urban planners who have been involved in urban planning, transport planning, and urban design projects in Wuhan. Based on results generated from interviews, most viewpoints were measured in a five-point Likert scale. For example, in response to the question, "To what extent do you agree that cycling in Wuhan is safe?" participants could choose from the following answers: strongly disagree, disagree, neutral, agree, or strongly agree. These five answers are coded from 1 to 5 as ordinal data. The Sign Test was conducted using the software SPSS 25.0 to determine if planners as a group are inclined more towards either end of the scale.

The questionnaire survey (see Appendix C) was conducted among practicing planners in Wuhan between June 12 and June 22, 2019. A pilot study was conducted first among five planners and revisions were made based on suggestions received. The final form was distributed via an online questionnaire survey service, which are available in formats that suit both phones and computers. Ten planners from nine planning organizations in Wuhan were invited to spread the link of the questionnaire to their colleagues and any planners they knew.

In total, 129 valid responses were received, including 74 planners (57.4%) who have been directly involved in cycling infrastructure planning and implementation. As depicted in Table 4.2, there is a general balance between male and female planners. Most participants were less than 40 years old and had a bachelor's or master's degree.

Table 4.2. Characteristics of participants

	N	Percentage (%)
Gender		
Female	67	51.9
Male	62	48.1
Age		
< 30	69	53.5
30–39	51	39.5
40–49	8	6.2

50–59	1	0.8
Education level		
Below bachelor's degree	6	4.7
Bachelor's degree	59	45.7
Master's degree	60	46.6
Doctoral degree	4	3.1
Major of the highest education degree		
Landscape architecture	39	32.2
Transport planning	18	14.9
Civil engineering	16	13.2
Environmental design	16	13.2
Urban planning	14	11.6
Others	18	14.9

4.3 Results

4.3.1 Planning artifacts

The current plan related to cycling at the city level is *Wuhan Cycling and Pedestrian Transportation and Greenway System Planning 2016-2030* (henceforth referred to as the Non-motorized Transport Plan). Unlike many cities in European countries, there are no separate plans, planners, or planning departments for cycling in Wuhan (this is true of many other Chinese cities as well). One planner (W6) explained that plans for cycling should be considered together with plans for walking and the urban environment as a whole; therefore, it is difficult to establish a plan specifically for cycling. According to the Non-motorized Transport Plan, when space was limited, pedestrian transport was a higher priority than cycling in terms of installing infrastructure.

In the central districts of Wuhan, there are 460 km of bikeways. The plan is to build 2455 km of bikeways in total, including 1141 km physically separated from motorized traffic. In terms of the form of bikeways, many interviewees prefer physically separated cycle lanes with railings or green belts. They think it is ineffective to build cycle lanes with painted lines because they are not safe and are easily occupied by motorized vehicles. All the interviewees noted that the existing cycling infrastructure is inadequate and suffers from a lack of maintenance and design (e.g., lack of street-crossing lanes and signals) (Figure 4.3). This was confirmed by the questionnaire survey: only 5.4% of planners feel satisfied with existing cycling conditions. Most planners tend to be unsatisfied ($Z=-8.500$, $p<0.001$, Sign Test). Interviewees consider the poor cycling conditions to be a historical result of an auto-oriented urban design in which many separated cycle lanes have been changed into motorized traffic lanes in recent decades.

Figure 4.3. Uncomfortable cycling conditions.

Cycle tracks are narrow and lack maintenance (left). Street facilities are built on cycle tracks as physical barriers (right).

4.3.2 Planning environment

4.3.2.1 Planning principles

As regards the principles of urban and transport planning, there was a consensus among the interviewees that there has been a shift from car-oriented principles to people-oriented in 2012 in accordance with the national policy for improving the non-motorized travel environment. As a result, walking and cycling are receiving increasing attention in street design. One planner elaborated:

> In the previous development of Wuhan, we aimed to firstly satisfy the designed function of a road, which is normally car-oriented. But now, with the development of the city and the increase in our standard of living, people are demanding a higher quality of travel. So now when we design for streets, we would consider pedestrians first, then cycling, then public transport, and lastly motorized transport (W8).

According to the Non-motorized Transport Plan, cycling infrastructure aims to be safe, coherent, convenient, comfortable, eco-friendly, and attractive. The long-term aim of the daily travel modal share is to achieve the "442" structure, i.e., 40% public transport, 40% non-motorized transport, and 20% motorized transport. There is no specific written aim for the modal share of cycling. But two planners (W3−4) mentioned that the current aim for cycling is 20%, which is the same aim that was set in 2008. One planner noted, "[w]e hope to maintain a modal share of 20% because it is not quite possible to increase it" (W3).

4.3.2.2 Shared assumptions of challenges

The above-mentioned concept of people-oriented design is consistent across the written plans and guidelines as a basic principle. However, this is not yet embedded in the actual planning practices because of a variety of challenges. According to the content analysis, a total of 13 challenges were identified (Cronbach's alpha = 0.913). The challenges are related to planning and implementation (inconsistent plan implementation, insufficient road space, lack of a systematic plan, specific design guidelines, and a compulsory standard), social and cultural issues (people's unruly travel behavior, pressure from car culture, and people's reluctance to cycle), political will (lack of political support and commitment, lack of communication and campaign, inconsistency and short-termism of policies, and lack of government investment), and commercial issues (unsustainable DBS business model). An overview of planners' attitudes toward different challenges is presented in Figure 4.4.

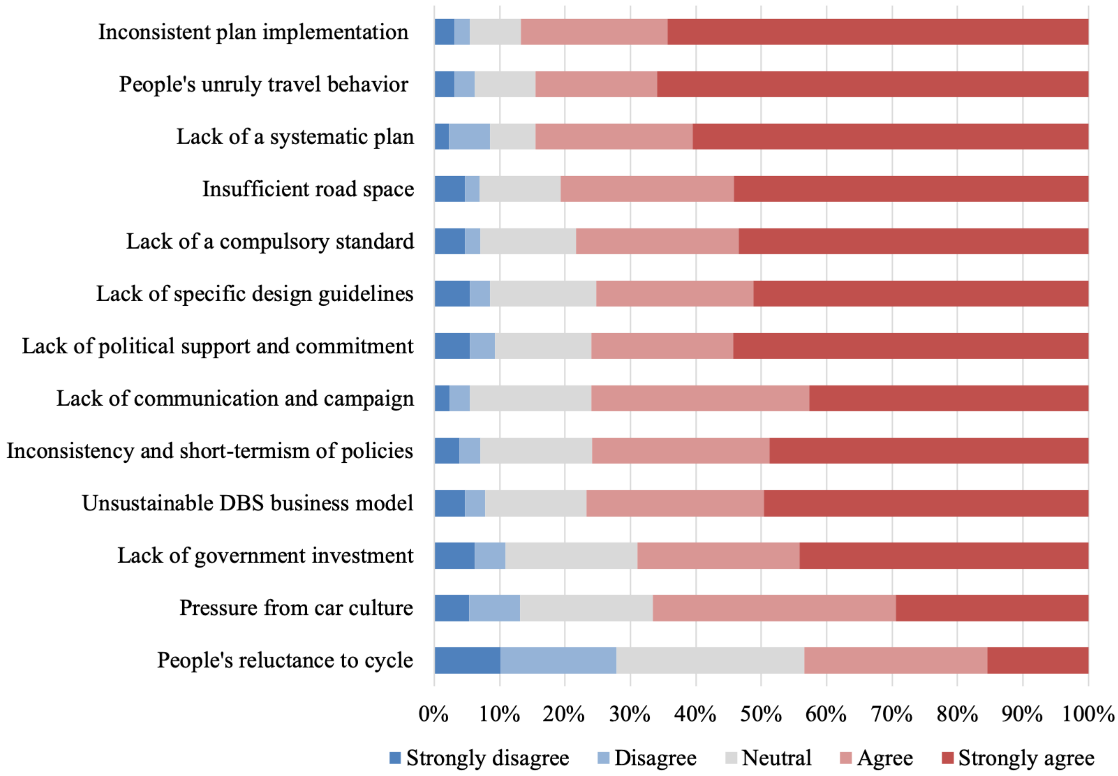

Figure 4.4. Planners' attitudes toward various challenges in improving cycling condition (N=129).

Table 4.3. Results of the sign test for different challenges

Survey item [a]	Observed Median	Sign Test	
		Z	*p*-value
Inconsistent plan implementation	5	9.534	< 0.001
People's unruly travel behavior	5	9.245	< 0.001
Lack of a systematic plan	5	8.855	< 0.001
Insufficient road space	5	8.843	< 0.001
Lack of a compulsory standard	5	8.677	< 0.001
Lack of specific design guidelines	5	8.179	< 0.001
Lack of political support and commitment	5	8.104	< 0.001
Lack of communication and campaign	4	8.783	< 0.001
Inconsistency and short-termism of policies	4	8.507	< 0.001
Unsustainable DBS business model	4	8.429	< 0.001
Lack of government investment	4	7.291	< 0.001
Pressure from car culture	4	6.700	< 0.001
People's reluctance to cycle	3	1.981	0.048

Note: [a] variable scaling (1 = strongly disagree, 5 = strongly agree).

According to the Sign Test for median (Table 4.3), the results indicate that Wuhan planners tend to strongly agree with all the investigated challenges in regard to planning and implementation, namely inconsistent plan implementation, lack of a systematic plan, insufficient road space, lack of a compulsory standard, and lack of specific design guidelines. The challenge of inconsistent plan implementation is agreed on by most participants (86.8%). This is partly due to the large-scale and urgent development of the rapid transit system, which creates plenty of construction sites, leading to uncomfortable cycling conditions and the delay of cycling infrastructure construction (W2−5). Regarding the aim of building 2455 km of bikeways, there is a lack of both a clear timeline and a list of resources for implementation. In addition, there lacks a systematic plan regarding different parts of cycling infrastructure, for example, cycle parking facilities, traffic lights, and shade for cyclists (W8).

Several types of political challenges are confirmed. Most planners strongly agree that there is a lack of political support. They also agree with challenges of inconsistency and the short-term nature of policies and lacking in government-led communication, campaign, and investment. Some interviewees (W3, W5, and W8−9) think that many barriers in bicycle planning and implementation are closely related to political challenges. As a result of development pressure, political support and investment are mainly focused on the construction of big infrastructure and have neglected the non-motorized environment.

With regard to social and cultural challenges, planners tend to strongly agree with the challenge of people's unruly travel behavior. Many car drivers randomly park in cycle lanes as well as on sidewalks (Figure 4.5), while e-cyclists seem to have conflicts with almost all types of road users. E-bikes in Wuhan are mostly in a scooter style with a speed between that of motorized transport and a conventional bicycle. E-cyclists sometimes use both motorized and non-motorized traffic lanes and traffic signals. As for DBS users, some park the bikes in a disorderly manner—for example, in the middle of a sidewalk or at the entrance of a store—leading to public aversion. In addition, planners tend to agree that pressure from car culture has hindered the improvement of cycling conditions. For instance, one interviewee noted that car drivers complain to the civil authorities when planners change a two-way road into a one-way road in order to create space for cyclists (W9).

Figure 4.5. Car parking on bikeways.

Another challenge that most planners tend to agree with is a lack of a sustainable DBS business model. Due to bike operators' efforts to obtain a high share of users, bikes from different operators flooded many streets and occupied numerous public spaces (Figure 4.6). The Wuhan government allowed for unrestricted growth in the beginning and then prohibited the introduction of new bikes in September 2017. Some companies went bankrupt in the free market competition, which led to financial losses for companies and users as well as a huge waste of (abandoned) bikes. In addition, some interviewees hope that DBS operators can share more data so that the government can collaborate with the operators efficiently (W2, W6).

Figure 4.6. Dockless bikes occupying pedestrian and public spaces.

<u>4.3.2.3 Shared values and informal rules in the planning process</u>

Facing all these challenges, the existing strategy is to construct bikeways selectively in a project-oriented way. As explained by one planner:

> There are more than 8000 km of road city-wide. It is not possible to establish [bikeways] everywhere widely. So, in recent years our experience is that you should first identify where you can implement. […] Each year we find some roads and make a list of projects to push their implementation. But it is not possible to make huge redevelopment changes in order to establish bikeways (W6).

Planners generally think that it is easier to design new roads in a people-oriented way, but it is very difficult to renovate existing roads. Insufficient road space is a significant barrier to improving cycling infrastructure. As frequently noted by interviewees, it is very difficult to find space for cycling on narrow roads (e.g., roads less than 30 meters wide) (W8–9). Despite the fact that minimum requirements for the width of bikeways on different levels of streets are set in written guidelines, the actual design of bikeways is normally based on how much room is left for cycling and on the demands of cycling.

There are four commonly noted rules for renovating existing roads. First, one must adhere to the limit of the road width and the required width for all the other elements on the road. These limits help to decide whether there is space left for cycling. Second, consider the function of the road; these include roads that are transport-oriented (e.g., main roads that prioritize motorized traffic), daily life-oriented (e.g., roads in residential areas), commercial-oriented (e.g., shopping streets that prioritize pedestrians), and landscape-oriented (e.g., roads in green spaces that prioritize aesthetic value). This helps decide the importance of cycling according to the type of road. One interviewee noted that daily life-oriented roads have the highest potential to reduce car space for cycling (W8). Third, consider the traffic flow of cycling provided by DBS operators, which helps identify whether there is a need to construct a cycle lane. Fourth, consider the status of the development of the road or area. For instance, areas with metro stations are considered to be in greater need of cycling infrastructure for a better Bike-and-Ride (B+R) service. In addition to these four considerations, planners also noted policy and knowledge learning from other big Chinese cities, with Shanghai and Guangzhou frequently mentioned (W2-3, W9).

Overall, when there is a lack of space, planners' judgments on the installation of cycling infrastructure are made in a pragmatic way rather than strictly according to the guidelines or with an ideal situation in mind. Most planners agreed that specific guidelines and a compulsory standard for cycling infrastructure are lacking. One interviewee (W9) mentioned, "when space is not enough [for adding a cycle lane], many planners would not try hard to solve it." In this regard, it is possible that some practicing planners have flexible and even arbitrary design behaviors.

4.3.3 Societal environment

4.3.3.1 The role of bicycle transport

Most interviewees considered cycling an important mode of transport for short distances. However, some interviewees claimed that cycling is not suitable for commuting. Two interviewees (W1 and W3) emphasized that cycling in Wuhan should mostly be used for B+R, including one (W1) who explicitly noted that "cycling is only suitable for B+R as a connecting tool instead of a mode of transport." To explore more planners' opinions, questions regarding how suitable cycling is for commuting and what is a suitable distance for cycling were investigated in the survey.

Planners were first asked to what extent they agree that cycling is suitable as one of the main modes of commuting in Wuhan. As a follow-up question, they were asked to what extent, compared to cycling, do they agree that B+R is more suitable as one of the main modes of commuting (Figure 4.7). The results indicate that only 40.4% of participants agree that cycling is suitable. No evidence shows that most planners tend to agree (or disagree) that cycling is suitable as one of the major commuting modes (Z=- 0.928, p=0.353, Sign Test). However, most planners tend to consider B+R more suitable for commuting (Z=6.636, p<0.001, Sign Test).

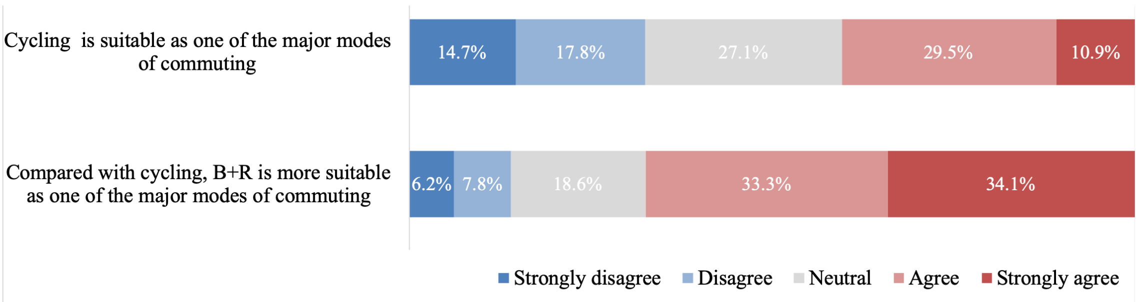

Figure 4.7. Planners' attitudes toward cycling and B+R as modes of commuting (N=129).

When interviewees claimed that cycling is not suitable for commuting, a common view was that “travel distance in such a big city is too long for cycling. …public transport should be the mainstream mode of commuting because Wuhan is such a big city …” (W1, also W2–3). A recent travel survey shows that the average commuting distance in Wuhan is 8.2 km, which is the shortest among the top ten GDP ranking cities in China (Jiguang, 2018). This report also shows that the percentage of people commuting under 5 km is 47.5% in Wuhan compared to 31.8% in Beijing and 30.6% in Shanghai. It is widely considered that 5 km is a short travel distance and is suitable for cycling (Heinen, Maat, & Van Wee, 2011; Simons et al., 2014; Van Dyck, De Bourdeaudhuij, Cardon, & Deforche, 2010). The travel behavior results in Wuhan indicate a huge potential for commuting by bike in Wuhan because nearly half of the commuters live within cycling distance of work. However, it is unexpected that 51.2% of the participants considered a suitable distance for cycling to be within 2 km (Figure 4.8).

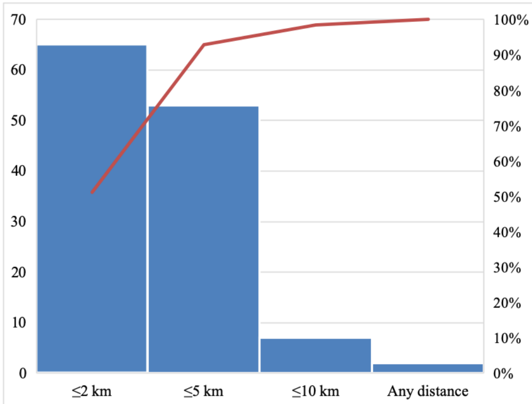

Figure 4.8. Planners’ opinions regarding a suitable distance for cycling for transport (N=129).

This obvious inconsistency in choosing between 2 km and 5 km is probably in accordance with the interviewed planners’ inconsistent understandings of the role of bicycle transport, which varied from “cycling for transport is irreplaceable” (W9) to “replaceable” (W1). The planner (W9) who thinks cycling is irreplaceable explained that cycling suits a distance beyond walking, while the other (W1) considers cycling a mere substitute for walking (for the first and last mile).

4.3.3.2 Perceptions of bicycle transport

During the explorative interviews, cycling is frequently portrayed as green (sustainable), practical for short distance, and fitness-improving. Many interviewees thought there was an obvious increase in cycle use after the introduction of DBS (or the concept of the sharing economy in general) (W2-3, W8, and W10). All the interviewees spoke highly of DBS because it has driven the revival of and planning for cycling. With easy access to bikes, many people have gradually taken to cycling as a daily routine. Interviewees also considered the increase in cycle use indicates people are inclined towards a relaxed lifestyle, representing a higher quality of life (W2-4, W8). On the other hand, interviewees thought that cycling in Wuhan might be uncomfortable during winter and summer and unsafe due to some unruly travel behaviors of motorists and e-bike users (W1-4). All these noted perceptions were investigated in the questionnaire survey (Figure 4.9, Cronbach’s alpha = 0.862).

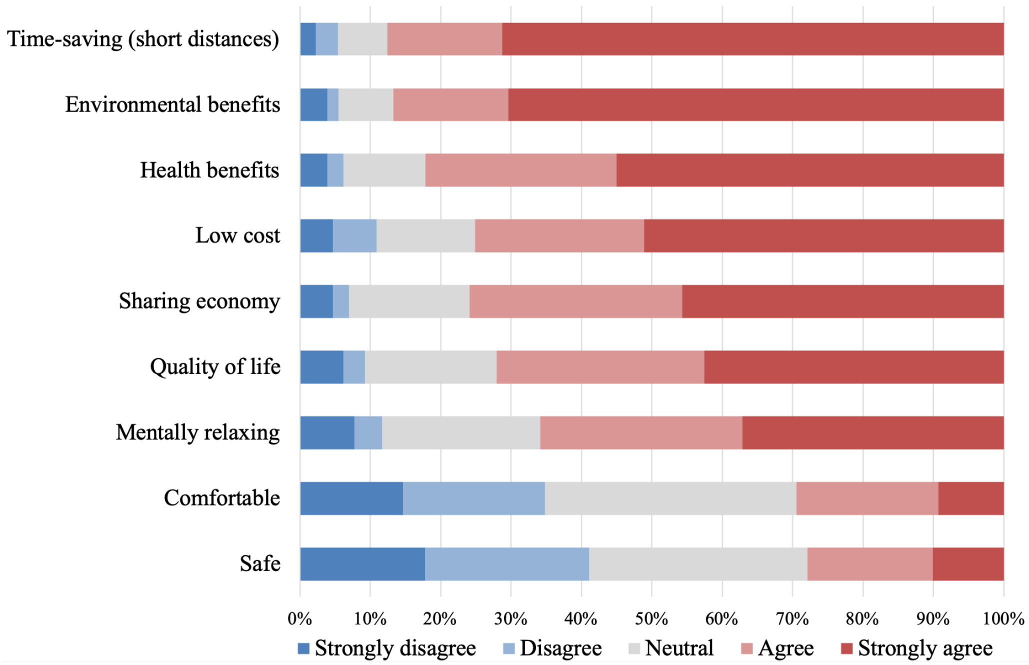

Figure 4.9. Results of planners' perceptions of bicycle transport (N=129).

A Sign Test showed that the median of all the factors other than safety and comfort were significantly different from 3 (neutral) (Table 4.4). This indicates that Wuhan planners as a group tend to strongly agree that cycling for transport in Wuhan saves time and money when traveling short distances and benefits health and environment. They also tend to agree that bicycle transport is mentally relaxing and represents the development of the sharing economy and a higher quality of life.

Table 4.4. Results of the sign test for planners' perceptions of bicycle transport

Survey item [a]	Observed Median	Sign Test	
		Z	*p*-value
Time-saving (short distances)	5	9.585	< 0.001
Environmental benefits	5	9.534	< 0.001
Health benefits	5	9.085	< 0.001
Low cost	5	7.783	< 0.001
Sharing economy	4	8.507	< 0.001
Quality of life	4	7.807	< 0.001
Mentally relaxing	4	6.900	< 0.001
Comfortable	3	-0.659	0.510
Safe	3	-1.696	0.090

Note: [a] variable scaling (1 = strongly disagree, 5 = strongly agree).

4.4 Discussion

4.4.1 Summary of findings

This study, guided by the culturized planning model, explored planners' perceptions and shared values of bicycle planning in Wuhan (Othengrafen & Reimer, 2013). Regarding planning artifacts, most planners are unsatisfied with existing cycling condition. For planning environment, while the planning principles are targeting a people-oriented and cycling-friendly street design, the actual improvement of the cycling infrastructure is selective and fragmented. A variety of challenges have been identified, in particular, planning and implementation challenges (e.g., inconsistent plan implementation and lack of a systematic plan), political challenges (e.g., lack of political support and commitment), social and cultural challenges (e.g., people's unruly travel behavior and pressure from car culture), and commercial challenges (unsustainable DBS business model). As regards the societal environment, planners agree with many benefits of cycling, particularly environment and health benefits, low-cost, and time-saving for short distances. However, there is no evidence to support that planners tend to agree that cycling is suitable for commuting in Wuhan. Planners are inclined towards cycling being used in combination with public transport to solve the first and last mile problem. Over half of the planners think a suitable distance for cycling is limited to 2 km despite the fact that travel distances within 2 km can be easily replaced by walking (Keijer & Rietveld, 2000).

In Wuhan, politicians and some planners think that, compared to public transport and private motorized transport, cycling is uncomfortable, inefficient for commuting, and of less economic value. It is possible that treating cycling as a complement to the public transit system is negatively affecting the role of cycling in the transport system. This echoes previous research that states that many planning discourses tend to devaluate cycling in spite of the fact that planning professionals and decision-makers are aware of the benefits of cycling (Smith, 2016). Some challenges are in line with findings in developed countries, in particular, lack of sufficient physical space and political support (Aldred, Watson, Lovelace, & Woodcock, 2019; Smith, 2016; L. Wang, 2018). However, some challenges are more representative of growing cities, for example, the large-scale rapid transit system construction which leads to inconsistent implementation of bicycle plans.

The importance of the informal rules in judgment-making echoes findings in pedestrian planning. For example, while planning for cars can be largely based on rule-based knowledge, planning for pedestrians more often employs judgment-based knowledge due to the emphasis that every site is unique and complex (Lindelöw, Koglin, & Svensson, 2016; Stangl, 2008). In Wuhan, there are some privileges of motorized transport planning that are not available to bicycle planning, for instance, large investments and a compulsory standard for the minimum width of a motorized traffic lane. Compared to some European cities, many of which are pioneers in bicycle planning, large Chinese cities have a less professional planning environment and a less supportive societal environment (Zhao, Carstensen, et al., 2018).

4.4.2 Planning and policy implications

Based on these findings, several planning and policy implications can be proposed. First, the identified challenges indicate that it is crucial to adopt a multifaceted strategy to improve cycling conditions. A systematic and long-term cycling plan should be devised to fill the gap between the written principles and actual planning practices. Bicycle planning should also be integrated into urban redevelopment and transport plans in order to reserve and redistribute space for cycling (Gerike & Jones, 2016). Moreover, there should be regular travel behavior surveys and public participation in planning to better meet public needs (L. Wang, 2018). This helps to refine not only the plans but also some shared assumptions.

Second, to devise a systematic and long-term cycling plan, a professional planning environment is critical (Curtis, 2008; Deffner & Hefter, 2015; Zhao et al., 2018a). In the face of the changing context, there could be more training in advanced planning concepts and tools, more information sharing among authorities, as well as more knowledge exchange between practitioners and researchers (Deffner & Hefter, 2015; Zhao et al., 2018a). It has been part of the Chinese planning culture that a key role for urban planners is to support local leaders and facilitate urban development and economic growth, but studies on more recent Chinese planning practices indicate that contemporary planners can play a more diverse and influential role in making decisions and resolving conflicts (Perlstein & Ortolano, 2015; Wang, 2013; Wu, 2015). Planners should be more committed to bicycle planning and convey pro-cycling values to the public through planning artifacts.

Third, many interviewees suggested that it is more efficient to promote cycling in a top-down manner with strong political support (W2, W8, and W10). The shift from car-oriented design to people-oriented in 2012 indicates the efficacy of a national policy framework for guiding regional and municipal planning in a state-led way. Therefore, a national cycling-specific strategy or policy framework is essential for improving the role of cycling from a higher level. Even though there are already some national strategies related to building a sustainable, low-carbon, eco, or people-oriented city, a more cycling-specific national strategy is lacking.

4.4.3 Limitations

The main limitation of this research is that, in the questionnaire survey, 93% of the respondents are less than forty years old. Although many planners in planning organizations are under forty, the author cannot ensure the survey sample is representative of all planners. Planners more than forty years of age are possibly more experienced and have a higher position in the planning organizations. It is possible that their values regarding bicycle planning are more decisive in planning practices. The results of this research might be more representative of younger practicing planners.

4.5 Conclusions

Overall, the findings of this research contribute to the understanding of the bicycle planning culture in large, growing cities where the role of cycling for transport is underrated. Although planners are not satisfied with existing cycling conditions, they find a systematic renovation difficult due to a variety of challenges. Consequently, a series of informal rules are adopted to improve cycling infrastructure in a project-oriented way. A significant gap exists between the written principles and actual planning practices. As regards the role of cycling in commuting, cycling is more often considered as a complement to local public transport. Planners agreed with many benefits of cycling, particularly environmental and health benefits; however, they have concerns regarding some fundamental prerequisites for cycling, for example, safety and comfort.

In order to develop sustainable, equitable, and efficient mobility in large growing cities, it is necessary to fully explore the role of cycling for transport, particularly for commuting. For example, further work could investigate the potential of bicycle commuting based on local travel behaviors, the level of job-housing separation, and the polycentric structure of the city. By mapping these potentials, researchers and planners can better inform decision-making at different levels. Additionally, compared to the environmental and health benefits of cycling, the social benefits were seldom mentioned by the interviewees. Wuhan remains a growing city with many low-income residents and a relatively high percentage of university students. Planning for cycling can improve access to jobs and services, improve social justice, and reduce transport poverty (Gössling, Schröder, Späth, & Freytag, 2016; Pucher, Peng, Mittal, Zhu, & Korattyswaroopam, 2007; Smith, 2016). More studies are necessary to further explore the social benefits of cycling in growing cities.

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5. Planning for cycling in big cities: a comparative study of Hamburg and Wuhan[2]

5.1 Introduction

There has been a growing interest in promoting cycling in big cities in recent years (Buehler & Pucher, 2012; de Lanversin, Suzuki, & Whitelegg, 2012; Lanzendorf & Busch-Geertsema, 2014). Many big cities are experiencing problems caused by increasing car use (e.g., traffic congestion, environmental pollution). Cycling, as a mode of transport, is promising as a means of reducing emissions, increasing traffic efficiency, and improving public health, social inclusion, and transport justice (Buehler & Pucher, 2012; Koglin & Rye, 2014; Smith, 2016). However, in many big cities, cycling has been marginalized, as it lacks a supportive environment (Koglin & Rye, 2014; Smith, 2016; C. Zhao, Carstensen, et al., 2018). In the face of high traffic volume, contested road space, and extensive public transport, promoting cycling is challenging (Buehler & Pucher, 2012).

To seek measures to promote cycling for transport, many studies have adopted a comparative approach. Comparative studies can help understand factors that affect cycle use (Haustein, Koglin, Nielsen, & Svensson, 2019; Heinen & Handy, 2012; Pucher & Buehler, 2006; Pucher, Garrard, & Greaves, 2011) and bicycle planning (Koglin, 2015b, 2015a; C. Zhao, Carstensen, et al., 2018). For example, by comparing Copenhagen and Stockholm, a study has underlined the importance of the organization of urban and transport planning department in bicycle planning (Koglin, 2015a). The integrated planning organizations in Copenhagen enable more knowledge exchange between planners with different expertise (Koglin, 2015a; C. Zhao, Carstensen, et al., 2018). Also, the comparison of bicycle planning in an experienced city and in a less experienced city helps generate policy implications (Marije de Boer & Caprotti, 2017; Pucher & Buehler, 2008; C. Zhao, Carstensen, et al., 2018). Some European cities with a high modal share of cycling are frequently referred to, for instance Copenhagen and Amsterdam (e.g., Marije de Boer & Caprotti, 2017; C. Zhao, Carstensen, et al., 2018). By comparing the state of cycling in London to the historic cycling transition in Amsterdam, researchers have identified barriers to promoting cycling in London and recommended policy, infrastructure, and cultural changes to promote cycling (Marije de Boer & Caprotti, 2017).

Chapter 3 and Chapter 4 study bicycle planning practices in Hamburg, Germany and Wuhan, China. Hamburg is the second largest city in Germany, while Wuhan is one of the megacities in China. Both cities are paying increasing attention to cycling and are aiming at improving conditions for cyclists. However, the two cities are planning for cycling in different contexts. First, Hamburg is more developed than Wuhan with regard to urban infrastructure and

[2] This chapter is developed based on findings from Chapter 3 and 4.

economic development. Hamburg experienced the rapid motorization process much earlier. The car ownership[3] in Hamburg was 421 per 1000 person in 2017, while in Wuhan it was 207 (Statista, 2018; Statistisches Amt für Hamburg und Schleswig-Holstein, 2017; Wuhan Bureau of Statistics & National Bureau of Statistics, 2018). As a well-developed city, Hamburg has already completed the basic public transport network. However, Wuhan is still constructing a rapid transit system on a large scale, leading to a huge number of construction sites around the city. Second, Hamburg is much smaller than Wuhan in terms of population and area. The differences in urban spatial structure might influence the travel distance (B. Sun et al., 2016). Third, the two cities have had an opposite trend in cycle use in recent decades (Figure 5.1). Hamburg has achieved a considerable increase in cycle use. The modal share of cycling in Hamburg increased from 7% in 1982 to 15% in 2017 (Follmer, 2018). In contrast, the modal share of cycling in Wuhan kept decreasing from 35% in 1987 to 18% in 2016 (Gu et al., 2019; L. Li et al., 2009).

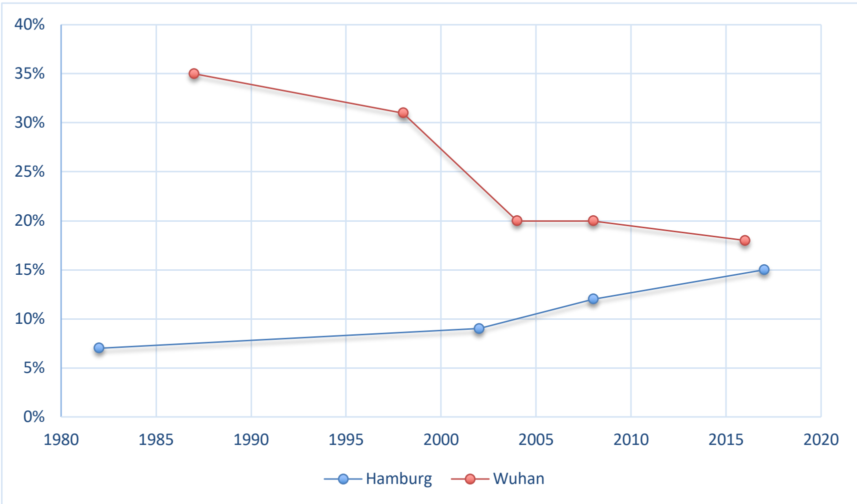

Figure 5.1. The modal share of cycling in Hamburg and Wuhan.

Source: Follmer, (2018); Freie und Hansestadt Hamburg, (2013); Gu et al., (2019); Li et al., (2009)

Given these contextual differences, it is possible that bicycle planning in Hamburg and Wuhan have different priorities, face different barriers, and adopt different measures. Based on narratives from interviews, Hamburg and Wuhan can be representative of big cities in the respective country in terms of the trend of cycling and bicycle planning. A comparative study of Hamburg and Wuhan helps to explore how bicycle planning differs in different contexts. This chapter is not aiming at providing a systematic examination on to what extent different contextual factors influence bicycle planning. Rather, it aims to further synthesize findings from Chapter 3 and 4 according to the culturized planning model (Othengrafen & Reimer, 2013). Therefore, the contextual factors discussed in this chapter largely depends on topics that emerged from the interviews in Hamburg and Wuhan. This comparative study aims to answer two questions: (1) What are the similarities and differences in bicycle planning in Hamburg and Wuhan? (2) How do local contextual factors influence bicycle planning from the

[3] The car ownerships are calculated based on the total number of population and private autos provided in the sources.

perspective of local experts? Based on the findings, this chapter further discusses how to improve the efficiency of bicycle planning, with an emphasis on Wuhan.

5.2 Methods

5.2.1 Analytical framework

This study employed a culturized planning model (see Table 5.1 for specifications) (Othengrafen & Reimer, 2013) to explore the similarities and differences in bicycle planning of Hamburg and Wuhan. The differences in spatial planning practices in different counties/cities are not only generated from their respective planning systems, but also from some informal institutional arrangements (Reimer & Blotevogel, 2012). Comparative studies play a role in investigating the influence of cultural differences on spatial planning (Booth, 2011; Keller et al., 1996; Knieling & Othengrafen, 2015; Reimer & Blotevogel, 2012). To achieve a contextualized understanding, the culturized planning model can help to explain some differences in planning practices and outcomes in different contexts (Knieling & Othengrafen, 2015; Othengrafen, 2014; Othengrafen & Reimer, 2013). Table 5.1 provides detailed explanations with regard to three layers of the model: planning artifacts, planning environment, and societal environment (Othengrafen & Reimer, 2013). Researchers have used the culturized planning model for comparing spatial planning in European member countries. Their findings suggest that under the pressure of European integration while planning policies and planning processes show a convergence, the underlying taken-for-granted assumptions can be different and be difficult to change (Knieling & Othengrafen, 2015). These further help to explain some differences in planning outcomes that, for example, although different European countries have some common aims, they set different priorities based on different taken-for-granted assumptions (Knieling & Othengrafen, 2015). Inspired by existing studies (Knieling & Othengrafen, 2015; C. Zhao, Carstensen, et al., 2018), this chapter employs this model to compare the bicycle planning in Hamburg and Wuhan and to further seek explanations.

Table 5.1. Culturized planning model for understanding bicycle planning practice

	Specification (Othengrafen & Reimer, 2013)	**Examples related to bicycle planning**
Planning artifacts	• Visible planning products and results	The condition of cycling infrastructure, cycling plans and design guidelines, and planning organizations and systems
Planning environment	• Cognitive frames, taken-for-granted values, and shared assumptions of the planning professionals	Planning principles and objectives, shared assumptions and norms in planning for cycling
Societal environment	• Underlying and unconscious societal beliefs, perceptions, and values affecting planning and planners' judgments	Values, perceptions, considerations of cycling, travel behavior, and lifestyle

5.2.2 Data collection and analysis

Data were collected through expert interviews and complemented by document analysis. Fifteen semi-structured expert interviews were conducted to obtain an in-depth and comprehensive understanding of the local bicycle planning process and development. Five interviews (H1–5) were conducted in Hamburg in 2017 and ten interviews (W1–10) were conducted in Wuhan in 2017 and 2018. Profiles of the interviewees are described in Appendix A.

Details on interview questions and the process of selecting interviewees are described in Chapter 3 and Chapter 4. In short, although the author conducted interviews in both cities, the interview questions (see Appendix B) and the selection of interviewees have similarities and differences. The similarity is that questions about changes in travel behavior and cycling conditions, the development of local bicycle planning and practices, and recommendations for improving cycling conditions were asked in both cities. In Hamburg, the key interview question was regarding barriers to implementing pro-cycling policies. To answer this question, the selection of interviewees aims to be diverse given that experts with different expertise can provide different angles of thought. In Wuhan, the key questions were regarding bicycle planning culture and challenges to improving cycling conditions. Therefore, interviewees in Wuhan are more homogeneous within the urban planning field, and more detailed questions regarding the planning process were asked.

All the interviews, except for H3, were recorded with permission. The recorded interviews were transcribed in texts and analyzed using content analysis (Schreier, 2012). The transcripts were coded one by one using NVivo 11 software. To facilitate the comparison of local cycling practice, document analysis was conducted with key bicycle plans in both cities. Although fewer interviews were conducted in Hamburg, the planning documents of Hamburg present detailed descriptions on planning objectives and process. Also, a recent survey on how people in Hamburg perceive cycling and their mobility behavior (SINUS-Institute, 2018) helps to explore the societal environment of bicycle planning in Hamburg. The main documents are as follows:

- *Wuhan Cycling and Pedestrian Transportation and Greenway System Planning (2016–2030)*
- *Alliance for Cycling (2016)* (Freie und Hansestadt Hamburg, 2016)
- *Cycling strategy for Hamburg: Progress report 2015* (Freie und Hansestadt Hamburg, 2015b)
- *Cycling strategy for Hamburg: Progress report 2018* (Freie und Hansestadt Hamburg, 2018)
- *Bicycle transport and quality of life in Hamburg* (SINUS-Institute, 2018)

5.3 Bicycle planning culture in Hamburg and Wuhan

5.3.1 Planning artifacts

Planning artifacts include written plans, the condition of cycling infrastructure, and planning organizations. The findings with regard to these aspects are summarized in Table 5.2.

Table 5.2. Summary of similarities and differences in bicycle planning artifacts in Hamburg and Wuhan

Planning artifacts	**Similarity**	**Difference**	
		Hamburg	**Wuhan**
Bicycle plan	–	A separate plan for cycling	No separate plan for cycling
Bicycle planning organizations	–	A separate department for bicycle planning	No separate department for bicycle planning
Condition of the cycling infrastructure	Inadequate and incoherent	Some B+R facilities are of high-quality	Unmaintained, poorly designed

Hamburg has developed a bicycle network plan since the 1990s and has initiated a bicycle action plan since 2008 with a range of interventions (Freie und Hansestadt Hamburg, 2007, 2015b, 2016). The current plan is *Alliance for Cycling* released in 2016. This is also an agreement, with signatures from representatives of the Senate, the borough offices and councils, and the mayor of Hamburg. This helps to ensure a basic consensus and a commitment among different districts to improving cycling conditions. Also, a progress report is published and updated every two or three years to specify to what extent the bicycle plan is implemented (Freie und Hansestadt Hamburg, 2015b). In Wuhan, the current plan related to cycling is *Wuhan Cycling and Pedestrian Transportation and Greenway System Planning (2016–2030)*. This plan provides general targets and design guidelines for deploying cycling infrastructure. There is no separate plan for cycling. The bicycle plan is produced together with walking and recreational cycling. Compared with the bicycle plan in Wuhan, the plan in Hamburg is more systematic, detailed, and compulsory.

Cycling infrastructures in both cities are insufficient. Existing bikeways in Hamburg are mostly from the 1980s, and they are narrow and do not meet current needs and standards. In Wuhan, many bikeways have been changed into motorized traffic lanes in recent decades. Existing bikeways are narrow, incoherent, and unmaintained. In terms of cycle parking facilities, Hamburg has introduced some high-quality facilities in recent years, including two-story parking racks and parking boxes. These types of facilities are not available to Wuhan, where many parking areas are defined by painted lines and marks, without racks or roofs. As noted by one interviewee (W1), the current investment is not enough to introduce new facilities.

With regard to planning organizations, there is a separate department for bicycle planning in Hamburg. There are cycling-specific planners, and there has been a cycling coordinator since 2015 to act as the public face of cycling and to coordinate activities across authorities. In Wuhan, there is no separate department for bicycle planning. Also, there is almost no cycling-specific planner.

5.3.2 Planning environment

Planning environment refers to bicycle planning objectives and principles, planning content, and the shared assumptions and cognitive frames of planning professionals. The similarities and differences in bicycle planning are summarized in Table 5.3.

Table 5.3. Summary of similarities and differences in bicycle planning environment in Hamburg and Wuhan

Planning environment	**Similarity**	**Difference**	
		Hamburg	**Wuhan**
Aim for the modal share	–	Increase the modal share of cycling to 25% by the 2020s	Maintain the modal share of cycling at 20%
The content of plan	Cycling infrastructure and parking facilities	Communication, public bike-sharing scheme	–
Priorities in action fields	–	Construct a bicycle network (Veloroutes)	Improve cycling infrastructure around metro stations
Main barriers in planning for cycling	Lack of physical space and political support	Disagreements among private stakeholders on road space redistribution	Inconsistent implementation influenced by the construction of a rapid transit system
Cognitive frames in planning and implementation	–	Improve the cycle infrastructure according to the written bicycle plan	Improve the cycle infrastructure according to the selected projects

With regard to *planning objectives and principles*, both cities aim to increase the quality and quantity of cycling infrastructure and to shape a safe, coherent, convenient, comfortable and attractive cycling environment. However, they have different priorities. In Hamburg, the priority is to construct and refurbish a citywide cycling network, namely the Veloroute network, which is aimed to be finished by the year 2020 (Freie und Hansestadt Hamburg, 2015b, 2016). By September 2018, 42% of all Veloroutes had been finished (Freie und Hansestadt Hamburg, 2018). In addition, Hamburg has a specific plan to increase the number of parking facilities (Freie und Hansestadt Hamburg, 2015a, 2016). In Wuhan, the improvement of cycling infrastructure is based on planners' selection. The selection is based on whether there is a huge need to build a cycle lane and whether there is enough space. In specific, planners prefer to improve the areas around metro stations first for better B+R service (W4 and W8). Descriptions of the deployment of bicycle facilities (e.g., parking facilities and traffic signals) are also presented in an open way.

In terms of *targets for modal shifts*, Hamburg aims to increase the modal share of cycling to 25% by the 2020s (Freie und Hansestadt Hamburg, 2016). However, Wuhan has no specific aim for increasing the cycling level. Some planners hope to maintain the modal share of cycling at 20% because they think it is not possible to increase the cycling rate (W3–4). In comparison, Hamburg has a more integrated planning system with detailed plans for realizing the objectives, as well as a more ambitious aim for increasing the modal share of cycling. In Wuhan, although there are written aims for constructing a coherent and convenient cycling environment, the planning and implementation of cycling infrastructure are unfocused and selective.

With respect to *planning content*, as described above, both cities have action fields for bicycle infrastructure (e.g., cycle lanes) and parking facilities. The major difference is that communication and the development of a public bike-sharing scheme (StadtRAD) are part of Hamburg's planning content, while they are not in Wuhan. There is no cycling campaign, education on cycling, or other programs in Wuhan. Urban planners in Wuhan had planned for the public bike-sharing scheme before, but now the scheme is replaced by the DBS schemes, which are mainly planned by private operators. The bicycle planning in Wuhan mainly concerns the provision of facilities.

In terms of the *implementation process*, planners in both cities found that the installation of cycling infrastructure should depend on the condition of each street. To create a supportive environment for cycling, a key issue is to allocate more space for cycling. However, both Hamburg and Wuhan have been developed in a car-oriented way in the last few decades, and road space has been a contested resource. Planners in both cities found it very hard to find space for cycling. The frequently noted restrictions include space used for other modes of transport, car parking, street trees (Hamburg), and green belts (Wuhan). When interviewing experts in Hamburg and asking them how they perceive bicycle planning in China, they assumed that it would be easier because streets in Chinese cities are much wider. It is true to a certain extent that streets in Wuhan are wider than those in Hamburg. However, planners in Wuhan still feel that too little space can be created for cycling.

In both Hamburg and Wuhan, a lack of political support has been a critical barrier to policy implementation. However, the way that the barrier obstruct policy implementation is different because the two cities have different political systems. In Hamburg, different districts can have different political majorities. While some parties are pro-cycling, some are not. Some politicians think that reallocating space for cycling would reduce the efficiency of motorized traffic, and thus further negatively impact the economy of Hamburg. Thus, it might be hard to implement pro-cycling policies in some specific districts. In Wuhan, although the whole city is led by one party, the central government is pro-growing rather than pro-cycling. There is a significant lack of political will because local politicians believe that the construction of a rapid transit system could achieve a more visible political impact than the construction of the cycling infrastructure.

There are two main differences in terms of implementation. First, in Hamburg, planners and implementers have to negotiate with local residents when deploying cycling infrastructure. The process can be time-consuming and difficult when facing residents' different opinions. In Wuhan, most residential areas are enclosed, and planners only have to plan for the public roads. Therefore, there is very little negotiation between planners and residents. Second, in Wuhan, cycling infrastructure construction has to wait for the construction of a rapid transit system.

Overall, planners in Hamburg aim to improve the conditions for cycling step by step according to the written plans. Improving cycling conditions is considered as a solution to many existing challenges, as it can benefit both the transport system and society (Freie und Hansestadt Hamburg, 2016). The related values include sustainability, social justice, and livability. Planners in Wuhan also consider the improvement of cycling conditions can contribute to sustainability and livability, but values related to social justice are seldom mentioned.

5.3.3 Societal environment

The societal environment refers to planners' underlying attitudes and unconscious thoughts towards aspects in regard to cycling, general travel behavior, and lifestyle. The findings in regard to these aspects are summarized in Table 5.4.

Table 5.4. Summary of similarities and differences in societal environment of bicycle planning in Hamburg and Wuhan

Societal environment	**Similarity**	**Difference**	
		Hamburg	**Wuhan**
Societal perceptions of cycling	Environmentally friendly, fitness-improving, convenient, low-cost, trendy, and subcultural	–	Inefficient, long-distance cycling is unnecessary
Factors that facilitate the bicycle planning	Cycle culture, the development of the bike technology	The increasing bike ownership and the decreasing car ownership among young generation	The sufficient provision of dockless public bikes
Factors that obstruct the bicycle planning	Car culture, economic value of motorized transport, safety concern	–	Growth-oriented consideration, the assumption that cycling is only a complement to public transport

There are similar values and perceptions of cycling in both cities. The most frequently mentioned values include being environmentally friendly, fitness-improving, convenient, low-cost, and trendy (H2, W2–4, W6–10, SINUS-Institute, 2018). Interviewees in both cities also mentioned that many people have the perception that cycling is subcultural and for low-income people (H2 and W1). Nevertheless, the benefits of cycling are important reasons for why cycling is becoming popular in both cities. There are also other reasons. In Hamburg, one planner (H2) mentioned that the development of bike technology is an important aspect. The private bikes are becoming more high-tech equipped for multiple functions. Owning a great bike is trendy among young people rather than owning a car. Also, the development of the e-bike (pedelec) is renewing people's awareness of traditional bikes. E-bikes are efficient and energy-saving (H2). On the other hand, in Wuhan, the key reason contributing to the popularity of cycling is the development of public bike-sharing systems (i.e., DBS schemes). In order to achieve a high share of users in market competition, DBS operators tend to oversupply their bikes and reduce the cost of using a bike. As a result, an increasing number of people are starting to cycle due to having easy access to a bike. However, the oversupply also caused public aversions to DBS because many public spaces are occupied by the dockless bikes. It is possible that people’s passion for cycling might be affected by the development of DBS schemes.

However, some narratives showed planners in Hamburg and Wuhan have different attitudes towards long-distance cycling. Interviewees in Hamburg did not make judgments on how long people should ride. They hope to facilitate city wide convenient cycle network and to reduce detours. For example, one planner (H2) noted “*it is very inconvenient to ride from Harburg to the city center…. The privilege of car use is not available to the cyclists.*” However, interviewees in Wuhan considered cycling for a long distance is unnecessary. For example, one planner (W3) noted “*we do not hope people cross the bridge by bike. The bridge itself is already over three kilometers. It is more convenient for people to take public transport.*”

Some planning professionals in Wuhan have ambivalent attitudes towards cycling. Based on a growth-oriented consideration, they think cycling is a slow mode of travel in nature. Cycling is frequently being compared with walking and public transport. Some planners think cycling is just a complement to transit access or a substitute for walking (H1 and H3). They believe public transport should be the reasonable and mainstream mode of commuting because Wuhan is a big city (H1–3).

5.4 Discussion and conclusions

5.4.1 Summary of findings

This chapter identified the similarities and differences in bicycle planning in Hamburg and Wuhan based on the culturized planning model (Othengrafen & Reimer, 2013). It is obvious that Hamburg has a more ambitious aim, a more systematic bicycle plan, and a more detailed implementation strategy. Wuhan lacks cycling-specific planning department and planners. There is also a higher degree of the involvement of the private stakeholders in the bicycle planning of Hamburg. Hamburg and Wuhan have different priorities in improving the cycling infrastructure. The priority in Hamburg is to complete the city-wide bicycle network, whereas in Wuhan it is to improve the areas around metro stations to facilitate the B+R. Planners and residents in both cities have an increasing awareness of the benefits of cycling. However, there are more ambivalent and negative attitudes towards cycling in Wuhan, for example, some planners believe that cycling is not suitable for commuting in a big city. This is in accordance with a study comparing attitudes and norms in bicycle commuting in Delft and Davis. Although residents in Delft and Davis have similar positive beliefs about the health benefits of cycling, there are more negative reactions to cycling in Davis, for example, the negative social norm that cycling is not appropriate in certain situations (Heinen & Handy, 2012).

With regard to the influence of the contextual factors in bicycle planning, the lack of sufficient physical space and political support are common barriers to improving bicycle infrastructure. The cycling culture – people’s willingness to cycle – shows a positive influence on bicycle planning in both cities. The development of a rapid transit system shows a considerable influence on bicycle planning in Wuhan. In the face of the urgent task of constructing a rapid transit system, cycling infrastructure can hardly be integrated into existing plans. Politicians believe that public transport is the mainstream mode of transport for such a big city and should be constructed first. Therefore, in current transport planning and urban development, cycling infrastructure planning and construction play a minor role. Overall, the two cities show different levels of professionalism of bicycle planning. The finding of this research is in line with a comparative study of Copenhagen and Beijing that Copenhagen has a more professional planning environment and a more supportive societal environment, whereas the role of cycling in Beijing is marginal (C. Zhao, Carstensen, et al., 2018).

The bicycle planning culture in the two cities can reflect some general urban or spatial planning culture in Germany and China. The finding that social justice is one of the shared values in the bicycle planning in Hamburg but not in Wuhan echoes previous findings that social justice is important in German spatial planning (Knieling & Othengrafen, 2015). There is a lack of sufficient concern on social benefits in Chinese urban planning (Wu, 2015). The systematic and detailed bicycle plan in Hamburg represents the German planning system's tradition of being scientific and accurate (Keller et al., 1996; Knieling & Othengrafen, 2015), whereas the marginalization of bicycle planning in Wuhan reflects a pro-growth consideration and judgment in Chinese planning culture (Wu, 2015). Studies have found that although there are many differences in the planning culture of different countries, serving for public interests is frequently a shared value among planners (Keller et al., 1996). In terms of bicycle planning, planners in Wuhan are more often considering the public interests with their individual assumptions, for example, believing that there is no need to cycle for a long distance, or, public transport can better serve the public. Many planners' assumptions are not based on empirical research. This might be explained in part by the lack of public participation in the bicycle planning of Wuhan.

5.4.2 Planning and policy implications

Although there are significant contextual differences between Hamburg and Wuhan, some experiences in bicycle planning of Hamburg can provide implications for Wuhan. First, experience from Hamburg suggests that establishing a separate department with cycling-specific planners helps to facilitate a more professional bicycle planning environment. Second, a systematic bicycle plan detailing different action fields can help to guide practitioners from different organizations. The plan should better be open to the public. This helps in ensuring a basic commitment to bicycle planning and conveying a pro-cycling value to the public. Third, as the cycling coordinator of Hamburg has been playing a key role in the cycling promotion of Hamburg, the government of Wuhan can possibly also assign a main responsible person who can oversee the whole implementation procedure and collecting public opinions. This helps to ensure a sense of leadership for cyclists. Fourth, it is necessary to provide high-quality cycling infrastructure where space allows. Last but not least, there should be more public participation and communication in bicycle planning, as well as more education on traffic regulations. For example, in Germany, there are training courses for schoolchildren on how to cycle safely (Pucher & Buehler, 2008; Pucher & Dijkstra, 2000).

5.4.3 Limitations

There are several limitations in this comparative study. First, the exploration of how local contexts influence bicycle planning only focused on factors that were mentioned in the interviews. Many other possible influential factors, such as economic development, spatial structures, and power relations between planning organization, are not examined in this study. Second, as shown in Chapter 5.2.2 Data collection and analysis, the interview protocols and the number of interviews in Hamburg and Wuhan are different. Since only five interviews in Hamburg were conducted, it is possible that the bicycle planning culture of Hamburg is not fully explored.

5.4.4 Recommendations for future research

This study revealed the differences in the level of professionalism of bicycle planning in Hamburg and Wuhan; however, a study of policy learning or policy transfer is beyond the scope of this research. Planning artifacts and planning environment are easier to be learned and adapted from one country to another, but it is hard to change the underlying societal environment (Knieling & Othengrafen, 2015). More research is necessary to figure out how some effective pro-cycling policies can be translated from an experienced city to an inexperienced city. For instance, future research can investigate local stakeholders' perception and acceptability of cycling strategies from abroad, and further assess the synergies and conflicts between stakeholders or between policies.

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6. Synthesis and conclusions

6.1 Summary of the main findings

Objective 1. Exploring the relationship between built environment and AT

- What are the recent findings on the relationship between the objectively measured neighborhood built environment and AT?

According to a systematic literature survey across four electronic databases, 51 articles published between 2005 and 2017 were identified, and 12 built environment factors were extracted. Most studies examined factors related to walkability and accessibility. Table 6.1 shows the main findings on the relationship between the objectively measured neighborhood built environment and walking and cycling for transport respectively. It is obvious that there are more findings on walking for transport than on cycling for transport. This is possibly because the number of studies on walking (n=35) is greater than that on cycling (n=17). Street connectivity shows a convincing positive relationship with both walking and cycling for transport, while access to destinations and neighborhood aesthetics show inconsistent results.

Table 6.1. Summary of findings on the relationship between the objectively measured neighborhood built environment and AT

	Positive relationship	**Not related**	**Negative relationship**
Walking for transport	Residential density Land use mix Street connectivity Retail land use Walkability Sidewalk Access to destinations	Neighborhood aesthetics	-
Cycling for transport	Street connectivity Bike lane	-	Access to destinations Neighborhood aesthetics

- Do different study designs generate different results?

Studies that use different study designs can generate different results, particularly using different analyzed geographic units and different measurements of AT. Two studies (Cervero et al., 2009; Lee & Moudon, 2006a) found that using different analyzed geographic units can generate inconsistent results. Five studies (Lee & Moudon, 2006a; L. Ma & Dill, 2015; McCormack et al., 2012; Mertens et al., 2017; Owen et al., 2007) found that using different measurements of AT can lead to inconsistent results. One study (Oliver, Schuurman, Hall, & Hayes, 2011) found that land use mix has inconsistent relationships with walking to different destinations (e.g., services and work). Therefore, it is crucial to choose suitable geographic units and measurement of AT and reduce the mismatch in the relationships.

- What directions can we provide for future research?

First, more studies on cycling behavior and cycling environment are needed. Second, more studies are necessary to figure out at which geographic unit different built environment factors should be measured to reduce the mismatch in the relationship between built environment and AT. Third, the role of self-selection factors and the differences in the relationship between built environment factors and different measurements of AT should be further explored. Fourth, more longitudinal studies and more studies in countries outside North America and Australasia are needed to better understand the relationship between the built environment and AT in different contexts.

Objective 2. Exploring barriers to implementing pro-cycling policies

- What are the barriers to implementing pro-cycling policies in Hamburg?

Drawing on expert interviews, the frequently mentioned barriers are lack of space (n=12), lack of political support (n=10), lack of evaluation of travel behavior and demand (n=6), time-consuming negotiation with private stakeholders on road space redistribution (n=4), and people's reluctance to give up on-street car parking space (n=4).

- What are the underlying reasons for the barriers?

Lack of space

Many of existing bikeways in Hamburg were created by taking space from sidewalks during the 1970s and 1980s. With increasing bicycle use, these bikeways cannot meet people's needs, and it is necessary to redistribute street space for cycling. However, most areas of the city are already built up. It is hard to take the spaces that are being used for other purposes (e.g., car parking, buildings).

Lack of political support

Interviewees considered that the overall transport policies tend to be more supportive of motorized traffic. There is insufficient political support for taking more push measures to restrict car use and facilitate cycling. For example, some politicians believe the speed limits would decrease the efficiency of logistic transport for the harbor, and thus negatively impact the backbone of the city's economy.

Lack of evaluation of travel behavior and demand

There is no frequent travel behavior survey in the city. Possibly because Hamburg started a cycling promotion only a few years ago, more experience is needed to develop a more systematic planning for cycling. Also, frequent evaluation of travel behavior requires resources (e.g., labor, investment), and the resources for cycling are limited.

Time-consuming negotiation with private stakeholders on road space redistribution

People's reluctance to give up on-street car parking space

It is hard to redistribute car parking space for cycling. Many citizens are car owners. They prefer to park their cars outside where they live. Some shop owners believe that their customers would like to travel by car, and they prefer to keep the on-street car parking, despite some evidence indicating that removing the car parking space would not influence their retail negatively and would even benefit their business. The city has been constructed in a car-oriented way in the last few decades, and many people are used to their lifestyle with the privilege of car use.

Objective 3. Understanding the bicycle planning culture and challenges in a growing city

- How do planners view cycling for transport in a growing megacity?

There is no evidence that planners tend to agree (or disagree) that cycling is suitable as one of the major commuting modes. However, there is strong evidence that planners consider B+R more suitable. Planners generally believe cycling is time-saving for short distances, sustainable, good for health and low cost. They also tend to agree that represents the boost of the sharing economy and a high quality of life, as well as cycling is mentally relaxing. But they do not consider cycling is comfortable and safe.

- What are the major challenges of improving cycling conditions?

A variety of challenges have been identified, in particular, planning and implementation challenges (e.g., inconsistent plan implementation and lack of a systematic plan), political challenges (e.g., lack of political support and commitment), social and cultural challenges (e.g., people's unruly travel behavior and pressure from car culture), and commercial challenges (unsustainable DBS business model).

- How do planners make practical judgments for deploying cycling infrastructure and what are their underlying perceptions and values?

Planning for cycling infrastructure is more often based on road conditions, in particular, whether it is necessary to build cycling infrastructure and whether there is space. To decide whether it is necessary to build cycling infrastructure, planners check the traffic flow of cycling on the roads, the main function of the roads, and the location of the roads. Roads with a huge cycling traffic flow and metro stations are considered to be in greater need of cycling infrastructure. Planners believe that many people would use bikes as a complement to the metro. However, if the main function of the road is designed for certain purposes (e.g., commercial), the distribution of the road space will give priority to the designated purpose (e.g., very wide sidewalks for shopping streets without installing cycle lanes). To decide whether there is space, planners firstly check the limits of the road widths and the required widths for all the other elements on the road, then decide how much space is left for cycling.

Objective 4. Comparing bicycle planning in different contexts and exploring contextual influences

- What are the similarities and differences in bicycle planning in Hamburg and Wuhan?
- How do local contextual factors influence bicycle planning from the perspective of local experts?

Both Hamburg and Wuhan lack sufficient cycling infrastructure; however, Hamburg has cycling-specific plans, planners, and a planning department. The bicycle plan in Hamburg is more systematic with a more ambitious aim. In Wuhan, cycling plays a marginal role, and the bicycle planning is unfocused and unsystematic. The two cities have different priorities in bicycle planning, and they also face some different barriers. Since there is more participation of private stakeholders in Hamburg, it is difficult to reach an agreement among different stakeholders. In Wuhan, more difficulties regarding uncivilized travel behavior are mentioned. Also, there are more conflicts between constructing cycling infrastructure and public transport infrastructure. In respect of the societal environment, cycling in both cities is perceived as sustainable, practical, and fitness-improving. There are more ambivalent and negative attitudes towards cycling in Wuhan.

In both cities, the lack of sufficient physical space and political support are barriers to the improvement of bicycle infrastructure. People's willingness to cycle shows a positive influence on bicycle planning. The construction of public transport infrastructure shows a considerable influence on bicycle planning in Wuhan, but not in Hamburg, where a city-wide public transit network is already established. In Wuhan, the taken-for-granted norm that cycling for transport is not suitable for a big city is negatively affecting the role of cycling.

6.2 Discussion

In general, this thesis has provided a deep insight into different aspects related to cycling as a means of transport, in particular, a supportive built environment, planning culture and policy implementation. By exploring the relationship between the built environment and AT, the findings suggest that the provision of bikeways and well-connected streets is associated with an increasing level of cycling for transport. This provides guidance for practitioners in urban design for creating a cycling-friendly environment.

Following this theoretical study, empirical studies were conducted to explore bicycle planning and policy implementation in different contexts. Given the context that many pro-cycling policies are being implemented in Hamburg, this research identified the main barriers to policy implementation. The results underlined the barriers of a lack of sufficient physical space, travel surveys, political support, and support from private stakeholders. These barriers suggest that although the bicycle plan in Hamburg is well written, it cannot be fully implemented in a timely manner without support from different stakeholders. Identifying major barriers and removing them is critical for effective pro-cycling policy implementation. The findings of this research can be of interest to researchers and practitioners, particularly those with a focus on large European cities.

Based on a better understanding of bicycle planning and policy implementation in Hamburg, this doctoral research then explored bicycle planning culture in Wuhan. The results suggest that the attitudes of local politicians and some planners towards cycling remain ambivalent, because the role of cycling for transport is considered as a complement to public transport. In the bicycle planning of Wuhan, planners' individual values and informal rules play a role more often than written principles and formal guidelines. These values and informal rules are embodied through a flexible planning approach, leading to an incoherent cycling condition. The finding of this research contributes to the understanding of bicycle planning practice in growing cities, where cycling for transport does not have a legitimate role.

To shift from car-oriented planning to cycling-inclusive planning, a multifaceted and integrated training of urban and transport planners is crucial. Some European cycling-friendly cities have provided practical guidance (e.g., the Dutch CROW principles) to facilitate bicycle planning within and outside Europe. For example, as mentioned in the first chapter, Bogota made significant progress in promoting cycling with the help of Dutch professionals and experiences (Pucher et al., 2010). However, when referring to some European measures in increasing the safety of cyclists (e.g., advanced stop line at intersections), some interviewees in Wuhan considered the measures to be impractical or unsuitable for Chinese cities, emphasizing the differences in population and traffic flow. By improving the planning skills and refining some taken-for-granted norms, a strategic planning paradigm can be developed for mitigating the conflict of interests in planning for cycling (Deffner et al., 2012). The increase in bicycle use in European countries is also considered to be a result of decades of training of urban and transport planners (Deffner & Hefter, 2015). Planners should play a proactive role in improving cycling conditions. Since Wuhan and many other growing cities are redeveloping the urban environment by upgrading the infrastructure, plans for cycling should be integrated into the urban development plans to shape an equitable, sustainable, and efficient urban road transport system.

6.3 Limitations

The limitation of each individual study can be found in respective chapters. Here a summary of main limitations is provided. With regard to the systematic literature review on the relationship between the built environment and AT, only articles written in English and published in peer-reviewed journals are searched. It is possible that some valuable findings in gray literature and in publications that were not written in English were missed.

As regards the case study in Wuhan and Hamburg, the 15 interviews were not consistent in that eight were conducted face to face and seven were conducted by telephone. The information collected from the telephone interviews might be less complete and rich than that from the face-to-face interviews. In the case study of Hamburg, the main limitation is that only five interviews were conducted. Although the main barriers are consistent across interviewees, it would be better if more interviews could be conducted to acquire perspectives from different angles. With respect to the questionnaire survey in Wuhan, most respondents are less than forty years old. The survey results might be more representative of younger practicing planners.

6.4 Recommendations for future research

First, the findings on the differences in the built environment correlates of walking and cycling for transport suggest that it is important to separate cycling from walking in both research and planning practices. The disparity between the number of studies on walking (n=35) and on cycling (n=17) suggests that it is necessary to have more studies on cycling for transport. Since study design was found to have a significant influence on the results, future studies should figure out a suitable geographic unit to measure the built environment and to increase the accuracy of the result. Also, there is a need for more studies in continents other than North America and Australasia and more longitudinal studies to better understand the relationship between the built environment and AT in different contexts.

Second, based on the finding of barriers to pro-cycling policy implementation, more studies are necessary for encountering these barriers. A lack of political support and insufficient physical spaces are found to be important barriers in both the Wuhan and Hamburg case studies. More research is necessary to explore how to gain stronger political support and how to create space for cycling infrastructure in space-scarce cities.

Third, the role of cycling for transport in large growing cities should be further explored. Many big Chinese cities have a polycentric spatial structure. More research could focus on how to facilitate short-distance commuting based on local travel behavior, the level of job-housing separation, and the polycentric structure. Future studies can also focus on how to achieve an integrated bicycle plan and how to plan for different types of cycling (DBS, private bikes, and e-bikes).

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APPENDIX A. Profile of interviewees

Code	Organization	Date
Hamburg		
H1	Hamburg University of Technology	20.06.2017
H2	Ministry of Economy, Transport and Innovation, Department of Bicycle Transport	19.09.2017
H3	Ministry of Economy, Transport and Innovation, Department of Road Transport	29.09.2017
H4	German Cyclist's Association (Hamburg branch)	18.09.2017
H5	Hamburg Public Transport Association	04.07.2017
Wuhan		
W1	Wuhan Transportation Research Institute	15.08.2017
W2	Wuhan Planning and Design Institute	25.08.2017
W3	Wuhan City Transportation Committee	21.08.2017
W4	Wuhan Land Resources and Planning Bureau	24.08.2017
W5	Beijing Mobike Technology Co., Ltd (Wuhan branch)	24.08.2017
W6	Wuhan Transportation Development Strategy Research Institute	26.10.2018
W7	Wuhan Planning and Design Co., Ltd	06.11.2018
W8	Wuhan Planning and Design Co., Ltd	27.11.2018
W9	Wuhan Municipal Engineering Design and Research Institute Co., Ltd.	27.11.2018
W10	Wuhan Planning and Design Co., Ltd	28.11.2018

Note: Face-to-face interview: H1, H4-5, W1-5. Telephone interview: H2-3, W6-10.

APPENDIX B. Question list for expert interview

Hamburg case study

Main questions

- What do you think about cycling as a means of transport in Hamburg in recent decades (e.g., the change in bicycle use and cycling infrastructure)?
- What do you think about current strategies in Hamburg to promote cycling?
- What are the current priorities in bicycle planning and cycling promotion in Hamburg?
- What are the main barriers, conflicts, and challenges in implementing pro-cycling policies?
- Do you think the new facilities/infrastructure, programs, and policies/legal measures to promote cycling have changed residents' travel behavior?
- Are there any differences in cycling in different areas of the city? For example, are there some places where lots of people like/dislike to ride a bike?
- With regard to individuals of different ages, gender, socioeconomic situation, education, etc., are there any differences in their attitudes towards cycling or in their cycling behavior?
- How would you compare the cycling promotion in Hamburg with that in other big German cities, for example Berlin, Munich and Frankfurt?
- Could you provide some recommendations for bicycle planning in Hamburg?

Wuhan case study

Main questions

- What do you think about cycling as a means of transport in Wuhan in recent decades (e.g., the change in bicycle use and cycling infrastructure)?
- What do you think about the role of cycling in the overall transport planning?
- Are there any measures in Wuhan that would improve cycling infrastructure? If so, what do you think about the current measures?
- Could you please briefly describe the flow/process of bicycle planning in Wuhan from the city level to the street level?
- Have you ever made any plans related to cycling? If so, how do you plan for cycling (resources, planning tools and methods)?
- What do you think about dockless bike-sharing schemes?
- What are the current priorities, conflicts, and challenges in bicycle planning and in improving cycling conditions in Wuhan?
- Could you provide some recommendations for bicycle planning in Wuhan?

APPENDIX C. Questionnaire of Wuhan Planners' Attitudes toward Bicycle Planning[4]

Dear Wuhan planners,

I am a PhD candidate from Leibniz Hannover University in Germany. Cycling condition is gaining increasing attention in Wuhan. However, in the context of rapid urban development, bicycle planning might encounter various difficulties and challenges. This questionnaire aims to learn about planners' attitudes and viewpoints of bicycle planning in Wuhan. Looking forward to your participation, thank you.

1. Is your current or previous occupation related to urban planning, or transport planning, or urban design in Wuhan?

   ☐ Yes ☐ No[5]

2. How do you usually travel to work? *(Give several answers if applicable.)*

   ☐ Walk ☐ Use a e-bike
   ☐ Use a normal bike ☐ Public transport
   ☐ Taxi/ car-sharing ☐ Private car
   ☐ Others____________

3. Your age?

   ☐ Younger than 30 ☐ 30-39
   ☐ 40-49 ☐ 50-59
   ☐ Over 59

4. Your gender?

   ☐ Female ☐ Male

5. Your education background (the highest level of education)?

   ☐ Below bachelor ☐ Bachelor
   ☐ Master ☐ Ph.D.

6. What is your major during your highest level of education?

____

[4] English translation. Original questionnaire in Chinese language.

[5] This is a filter question. If the answer "No" is chosen, the survey will turn to the last question (No.18) automatically. Questionnaires with a "No" answer for this question are treated as invalid.

7. During the past one year, how often do you use a bicycle (including an e-bike)?

▢ More than once each week ▢ a few times each quarter

▢ Almost never

8. According to your individual experience or observation, what do you think about the cycling condition of Wuhan? (Greenways that are mostly used for recreational purposes are excluded here.)

▢ Very unsatisfied

▢ Unsatisfied

▢ Neutral

▢ Satisfied

▢ Very satisfied

9. Do you have a private car?

▢ Yes ▢ No

10. According to your individual observation and experience, regarding cycling as a mode of transport in Wuhan, to what extent do you agree with the following viewpoints? (Cycling only refers to normal bikes, e-bikes are excluded here.)

	▢ 1 Strongly disagree	▢ 2 Disagree	▢ 3 Neutral	▢ 4 Agree	▢ 5 Strongly agree
Cycling alone is suitable as one of the main modes of transport	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
Compared to cycling, B+R is more suitable as one of the main modes of commuting,	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
Environmental benefits	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
Time-saving (short distances)	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
Safe	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
Comfortable	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
Low cost	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
Health benefits	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
Mentally relaxing	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
A symbol of the development of sharing economy	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
A symbol of the increasing quality of life	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5

11. Rank from 1 (most) to 6 (least) which types of infrastructure you think should be prioritized when designing or planning for a street (section)[6].

☐ Pedestrian infrastructure

☐ Cycling infrastructure

☐ Public transport infrastructure

☐ Private car infrastructure

☐ Green belt/ street green space

☐ Street facilities

12. How far do you think is suitable for travelling by a normal (non-electronic) bike?

☐ ≤2 km ☐ ≤5 km

☐ ≤10 km ☐ Any distance

13. To improve cycling condition of Wuhan, there might be various difficulties, barriers and challenges. To what extent do you agree that the following listed challenges exist in Wuhan?

	☐ 1 Strongly disagree	☐ 2 Disagree	☐ 3 Neutral	☐ 4 Agree	☐ 5 Strongly agree
Inconsistent plan implementation	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
People's unruly travel behavior	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Lack of a systematic plan	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Insufficient road space	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Lack of a compulsory standard	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Lack of political support and commitment	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Lack of specific design guidelines	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Lack of communication and campaign	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Inconsistency and short-termism of policies	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Unsustainable DBS business model	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Lack of government	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

[6] This question is not mandatory

investment					
Pressure from car culture	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
People's reluctance to cycle	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

14. Have you ever designed or planned for cycling infrastructure in Wuhan?

    ☐ Yes ☐ No[7]

15. What are your frequently used bases when designing/ planning for cycling infrastructure? (e.g., how do you decide the width of a cycle lane of a street) *(Give several answers if applicable.)*

    ☐ The level and function of the street designated in an upper level plan

    ☐ Street design guidelines and standards

    ☐ The specific environment of a street

    ☐ The leader or someone else's decision

    ☐ Personal preference

    ☐ Knowledge and suggestions from professional education or training

    ☐ Others_____________________________________

16. When street space is not enough for adding a cycle lane, to what extent do you agree with the following statements?

	☐ 1 Strongly disagree	☐ 2 Disagree	☐ 3 Neutral	☐ 4 Agree	☐ 5 Strongly agree
The street can be without a cycle lane.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
We can reduce car space for creating space for cycling.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
We can reduce pedestrian space for creating space for cycling	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
We can reduce street green belt space for space for cycling	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
We can apply for increasing the limited width of the street for creating space for cycling	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

[7] If the answer "No" is chosen, the survey will turn to the last question (No.18) automatically.

17. As regards existing cycling infrastructure development in Wuhan, to what extent do you agree with the following statements?

	▢ 1 Strongly disagree	▢ 2 Disagree	▢ 3 Neutral	▢ 4 Agree	▢ 5 Strongly agree
Wuhan is constructing urban infrastructure forcefully. We should prioritize the construction of public transport network. A detailed design and plan for cycling infrastructure should wait.	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
The cycling condition of Wuhan is improving.	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
The development of dockless bike sharing system promoted bicycle planning and implementation.	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
People's willingness to cycle promoted bicycle planning and implementation.	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5
The government's increasing attention on cycling promoted bicycle planning and implementation.	▢ 1	▢ 2	▢ 3	▢ 4	▢ 5

18. As regards cycling condition and bicycle planning in Wuhan, do you have any suggestions or opinions?

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____
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Thank you very much for your participation! If you have any questions, or if you are interested in a more in-depth interview, please contact me by e-mail or WeChat.

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Declaration of authorship

I declare that I have completed the doctoral thesis independently and have not used any sources or means other than those indicated. The work has not previously been submitted as a thesis or an examination paper.

Parts of the thesis have been published as individual papers in peer-reviewed journals.

1) Wang, L., & Wen, C. (2017). The relationship between the neighborhood built environment and active transportation among adults: A systematic literature review. *Urban Science*, 1(3), 29.

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Author Contributions: LW conceived and designed the study; LW and CW performed the data search; LW analyzed the data and drafted the manuscript; CW revised the manuscript.

2) Wang, L. (2018). Barriers to implementing pro-cycling policies: A case study of Hamburg. *Sustainability*, 10(11), 4196.

https://doi.org/10.3390/su10114196

Parts of the thesis have been submitted to an international peer-reviewed journal *Cities*.

3) Wang, L. Planning for cycling in a growing megacity: Exploring practicing planners' perceptions and shared values

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