Bachelor Thesis

Multimodal Transport for Sustainable Cities: Comparing the Integration of Public Transport and Cycling in Groningen and Berlin

by

Jakob Hausmann
S4982703

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Faculty of Spatial Sciences
Rijksuniversiteit Groningen
Supervisor: Christian Lamker

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Abstract: Improving multimodal transportation is one approach to making urban mobility more sustainable. Particularly, cycling and public transport show great potential as alternatives to individual motorised transport. Both modes show symbiotic effects as cycling expands the catchment area of public transport stops while the bike-train trip chain allows for covering longer distances than by bike alone. This research compares the provision and use of cycling-friendly infrastructure at train stations in Groningen and Berlin and its influence on the cities' respective modal splits. These cases were chosen as Groningen has the reputation of being a 'cycling city', while Berlin is renowned for its good public transport. Based on surveys and observations, cycling-friendly infrastructure in Groningen was found to be better in quality and quantity than in Berlin. This came with an increased modal share of cycling for access trips to train stations in Groningen. Consequently, Berlin can improve its bike-train integration by investing in improved infrastructure for bicycle parking, bike-sharing and improving the urban integration of cycling. This would offer viable alternatives to car traffic and, therefore, make mobility more sustainable.
Keywords: urban mobility, multimodal, cycling, public transport, bike-train integration

Table of Contents

1. Introduction and Research Problem

To counteract the existential threats of climate change and environmental degradation, Europe aims to become the first climate-neutral continent. As formulated in the European Green Deal, greenhouse gas emissions are aimed to be cut by 55 percent, compared to 1990 levels, by 2030, while a neutral balance should be reached in 2050 (European Commission, 2019). These ambitions have significant implications for the mobility sector. By 2050, Europe aims to achieve a 90 percent reduction in transport emissions (European Commission, 2020). With 22 percent, mobility is a major contributor to the European Union's (EU) emission budget (European Environment Agency, 2022). This underscores the urgency for reducing emissions within the mobility sector.

Besides emitting barely any greenhouse gases, promoting cycling offers further benefits for the sustainable transformation of urban areas. Following Gehl (2010), active modes such as cycling create lively cities as the slower speed increases the number of meaningful interactions between people. It is widely accepted that people on the streets create liveable, democratic and economically successful cities which is why the EU and more and more cities promote cycling (European Union, 2016; Gemeente Groningen, 2021; Senatsverwaltung Umwelt, Verkehr und Klimaschutz - Abteilung IV – Verkehr, 2021). Furthermore, high levels of cycling offer health benefits as regular moderate physical exercise decreases the risk of cardiovascular diseases, type 2 diabetes, cancer and obesity (World Health Organisation, 2022).

Active modes like cycling and walking cannot, however, satisfy every travel desire due to the physical activity they require and their comparably low speed and limited range. For longer trips, public transport can complement active mobility. While cars can offer high-speed, long-range, individualised transport, major drawbacks are their energy and space consumption, pollution, and social exclusiveness (Lah, 2019; Van der Werf, 2019). Furthermore, the external costs of individual motorised transport are multiple times higher than those of public transport, thus putting an economic burden on societies (Pisoni, Christidis & Navajas Cawood, 2022). Therefore, the modal share of the car is aimed to be reduced in the EU (European Union, 2016).

Cycling can be particularly valuable in combination with public transit. Kager, Bertolini and Te Brömmelstroet (2016) argue that the high speed of public transit combined with the flexibility and adaptability of the bicycle brings strong synergetic effects, which is why they

propose to consider bike and train as one transit mode. Public transit can be seen as the "[…] 'wormhole' capability to the cycling system in the connection between urban areas located further apart" (Kager, Bertolini & Te Brömmelstroet, 2016, p.217). Furthermore, its threefold higher speed compared to walking increases the catchment area for transit stations ninefold (Kager, Bertolini & Te Brömmelstroet, 2016). This increases the demand and, therefore, can offer economic benefits for public transport users, operators and the urban area.

While a rich body of research evaluates which spatial measures can help the integration of cycling and public transport for access and egress trips (Geurs, La Paix & Van Weperen, 2016; Kager, Bertolini & Te Brömmelstroet, 2016; La Paix, Cherchi & Geurs, 2021; Givoni & Rietveld, 2007; Pucher & Buehler, 2012), case studies often describe the built environment without investigating consequences to the modal split. Therefore, this thesis aims to investigate differences in the integration of cycling and public transport in Berlin and Groningen and how these contribute to the access and egress trip modal split. Both cities are known for their progressive transport policies while their approaches differ significantly. Berlin is known for having a dense public transit network comprised of a mass rapid transit system, overground (S-Bahn) and underground (U-Bahn), and many feeder and night bus lines. Groningen only has a bus system, which does not even enter the city centre. However, with about 50 percent of inner-city trips made by bicycle and an active share of about 75 percent (Centraal Bureau voor de Statistiek, 2020), active modes have a higher priority.

The research question and sub-questions are:

How does bicycle-friendly design at train stations promote sustainable mobility in Berlin and Groningen?

- *What is bicycle-friendly infrastructure?*
- *To what extent is bicycle-friendly infrastructure available at train stations and what is its quality?*
- *How does it influence access and egress trip mode choice?*

In this bachelor thesis, firstly, important concepts and dimensions of bike-train integration are discussed and an introduction to the cities of Berlin and Groningen is given. Afterwards, the methodology is presented, followed by a discussion of the results and a conclusion.

2. Literature Review

2.1. Sustainable Mobility

According to the Council of the European Union (2006), sustainable mobility aims to "ensure that our transport systems meet society's economic, social and environmental needs whilst minimising their undesirable impacts on the economy, society and the environment" (p. 10). According to Banister (2008), making mobility more sustainable consists of four dimensions. It requires, firstly, reducing the number of trips using technology, secondly, promoting a modal shift towards more sustainable modes, thirdly, reductions in trip length through land use, and, fourthly, efficiency increases through modern technological advancements. Of those dimensions, bike-train integration aims to achieve a modal shift from the car towards bicycle and public transport.

2.2. Mode Choice

In the Physical Activity through Sustainable Transport Approaches project (PASTA), Götschi et al. (2017) stated that mode choice is influenced by physical and individual determinants, which are, however, influenced by the social context. Besides external factors, such as weather and topography, physical determinants of mode choice are given in the built environment. This entails, on the one hand, land use, as high-density and mixed-use neighbourhoods promote the use of active mobility, and, on the other hand, the transport system and transport infrastructure. As suggested by Fosgerau et al. (2023), the provision of cycling infrastructure can induce a demand for cycling in the population. This is also represented in the transport-land-use feedback cycle proposed by Wegener & Fürst (1999), which however focuses more on the relationships between land use, transport system, accessibility and activities.

2.3. Integration of Cycling and Public Transport

Successful bike-train integration relies on the provision of infrastructure and a supportive climate for both modes in the population (Kager & Harms, 2017). This 'cycling culture' cannot, however, be created by infrastructure investments alone. It requires a complex interplay of policy, users and societal organisations (De Groot, 2016). Based on this complexity, there is no one-size-fits-all solution. Particularly for cycling, a variety of apparent and latent factors influence the success of a network and relevant changes (Kager & Harms, 2017). While taking the bicycle on the train appears to be the most favourable and comfortable solution, peak hour

demand can exceed capacity. The additional time and space required would reduce the cost- and space efficiency of public transit making the mode less attractive (Pucher & Buehler, 2012; Kager & Harms, 2017). Bike-on-board is thus hardly scalable to places with a high modal share of cycling such as Groningen. It can, however, help to increase transit ridership or temporarily compensate for poor provision of other components of a network (Kager & Harms, 2017).

2.3.1. Bicycle Parking Facilities

Based on the Dutch Railway customer satisfaction survey, Givoni and Rietveld (2007) found cycling to be most popular on the home end (see Figure 1) of a multimodal trip. Bicycle parking facilities should therefore accommodate safely storing bicycles and quick changes between the modes.

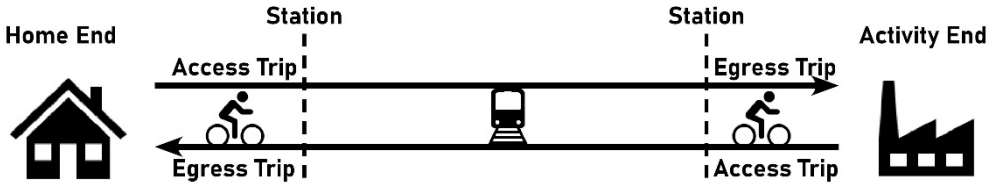

Figure 1 - Schematic Overview of a Multimodal Bike-Train Trip (Hausmann, 2024)

Experiences from the Netherlands show that, ideally, bicycle parking can be reached directly via cycling paths and is located as close as possible to the station entrance (Sully, 2016). There are different kinds of bicycle parking facilities ranging from simple bike racks on the sidewalk to bike stations which offer a variety of services and functions, such as repair centres or showers (Pucher & Buehler, 2012). Studies from Canada and the USA showed that one primary concern associated with bicycle parking is the risk of theft (Ravensbergen et al., 2018; Taylor & Mahmassani, 1996). While in North America bike lockers or bike cages are often used to reduce the risk of theft, Dutch cities rely primarily on guarded parking facilities (Pucher & Buehler, 2012). To reduce the exposure to weather, bicycle parking facilities are often sheltered varying from simple covers to fully indoor bike parking (Pucher & Buehler, 2012). Financial reasoning plays a significant role in mode choice. A study by Geurs, La Paix and Van Weperen (2016) in the Netherlands showed that after fares for guarded bicycle parking (1.25 €/day) were removed, the number of train users rose by eleven percent. Furthermore, the research showed that the proximity of bicycle parking to the platform and the availability of enough parking spaces are important as both reduce the time used for the change between the modes and therefore increase the attractiveness of bike and ride.

2.3.2. Bike-Sharing Services

While bicycle parking facilities can be very valuable in increasing the share of cycling at the home end of trips, good bike-sharing services can stimulate the use of bicycles at the activity end of trips (see Figure 1) as it is often more practical than having a second bike at the destination (Martens, 2004). Especially in urban centres, a variety of activities in different locations diffuses traffic which makes it harder to coordinate public transport and can lead to the success of bike-sharing services (Kager & Harms, 2017). Ma et al. (2020) found an increase in the modal share of both, cycling and public transport, and a reduction in the modal share of the car in densely populated urban areas following the introduction of bike-sharing. Bike-sharing services can be divided into more flexible free-floating systems and more efficient station-based systems (Cheng et al., 2020). A study from China showed that station-based systems are more efficient in areas of high travel demand concentrations, such as stations or commercial properties, while free-floating systems have advantages in high-density residential areas (Cheng et al., 2020).

Reviewing bike-train integration in Europe, North America, Australia and Japan, Pucher and Buehler (2012) distinguish between two types of bike-sharing that are attractive to different groups. Traditional bike-sharing services that charge a daily or hourly rate are more convenient for tourists or recreational cyclists. Public transportation bikes are more appealing to commuters who regularly need to take the bike as they charge over longer periods and offer discounts for public transport users. One example of such is the Dutch OV-bike (Public-Transport-Bike), which is available at 300 locations in the Netherlands and its usage is included in the public transport subscription (Nederlandse Spoorwegen, 2024). Upon its introduction, it brought a significant increase in the modal share of the bicycle for egress trips, while also increasing the train ridership by around 15% (Martens, 2007). Providing low-cost shared e-bikes is another option to increase the share of cycling as the higher speed enhances the catchment area even more.

2.3.3. Urban Integration

Kager, Bertolini and Te Brömmelstroet (2016) propose that for the successful integration of cycling with public transport, bike-train should be considered as one joint mode instead of two competing modes. Therefore, bike routes must be coordinated together with public transport to effectively respond to changes in the system (Kager & Harms, 2017). This entails that at

stations, cycling paths should be appropriately signed and lead directly to the parking facilities. Furthermore, they should be organised in a way that reduces interference with pedestrian traffic (Pucher & Buehler, 2012). Moreover, the trip to and from the station should be no longer than 5 km which is why employment centres and residential areas should have a public transport stop close by (Sully, 2016). Givoni and Rietveld (2007) found that people who live less than 3 km from a station are more than twice as likely to use a bicycle for the access trip than people who live further away.

Generally, to promote cycling as a transport mode, a city must have a well-developed cycling network. Following De Groot (2016), the quality of a cycling network is determined by its cohesion, directness, attractiveness, comfort and safety. La Paix, Cherchi and Geurs (2021) found that reducing delays on trips to the station has a stronger influence on choosing the bicycle as a feeder mode than reducing delays within the station. Using surveys and the Dutch National Transport Model, Geurs, La Paix and Van Weperen (2016) modelled a 16 percent increase in train ridership following a 5-minute reduction in cycling travel time caused by fewer interruptions on the route and priority at traffic lights. However, a 5-minute reduction on an access trip that normally takes 10-15 minutes seems unrealistic and La Paix, Cherchi and Geurs (2021) conclude that due to latent factors, modal shift estimations cannot be made purely based on infrastructural changes. These latent factors are, for example, the perceived quality of bicycle infrastructure, connectivity of stations and the general attitude towards cycling. Ignoring those latent factors would lead to an overestimation of the effects that improvements in the infrastructure have on the modal split (La Paix, Cherchi & Geurs, 2021).

Based on the previous literature review, Figure 2 shows a conceptual model that is used to answer the research question.

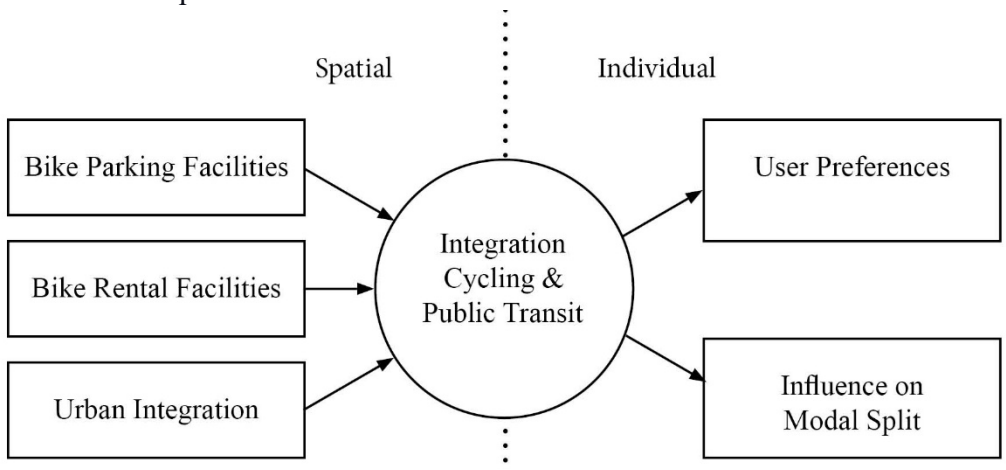

Figure 2 - Conceptual Model (Hausmann, 2024)

2.4. Cases: Groningen and Berlin

2.4.1. Groningen

Groningen is a city in the northeast of the Netherlands with almost 240,000 inhabitants. More than 90,000 inhabitants (38%) are below the age of 26 and about 65,000 (27%) study at one of the universities (OIS Groningen, 2023a). Groningen embraces the concept of the compact city and, thus, intensive, high-density use of urban areas and concentration of a mix of functions (De Roo, 1998). Consequently, suburbanisation is limited, and trips are shortened which supports cycling and the profitability of public transport (De Roo, 1998). Combined with a policy that restricts car transit through the inner city and the provision of an extensive network of cycling paths and other cycling infrastructure, Pucher and Buehler (2007) consider Groningen to be "[…] the most bicycling oriented city in Europe's most bicycling oriented country" (p.17). Consequently, car ownership is, with 0.56 cars per household, the second lowest in the Netherlands after Amsterdam (Gemeente Groningen, 2021). More than half of inner-city trips in Groningen are made by bicycle (see Figure 3).

In its mobility vision, Groningen further aims to promote the use of active mobility by offering more space and safety in the urban environment. This entails a reduction in space devoted to individual motorised mobility (Gemeente Groningen, 2021). The importance of the bicycle will be enhanced even further by accommodating a variety of bicycle types (e.g. e-bike, cargo bike) in urban planning. (Gemeente Groningen, 2021). Neighbourhoods are also aimed to become less car-dependent by mixing traffic flows, decreasing on-street parking and implementing speed limits. Furthermore, multimodality will be supported by acknowledging and using the potential of technology in shaping multimodal trips (Gemeente Groningen, 2021).

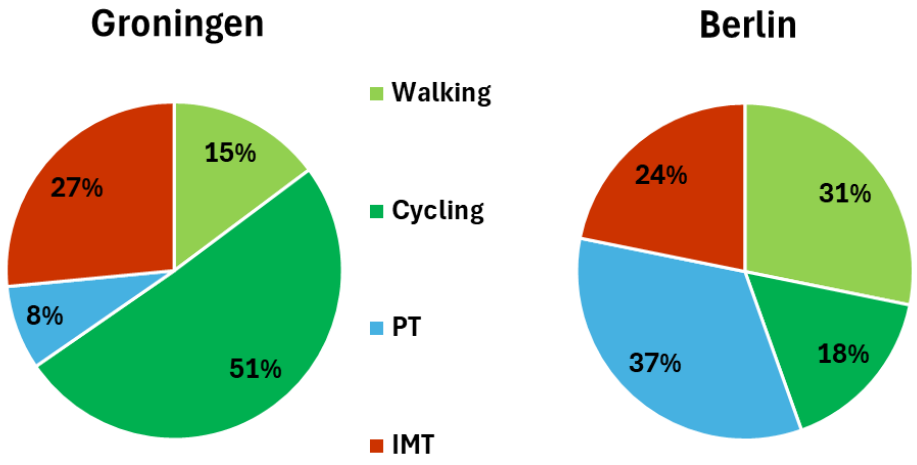

Figure 3 - Modal Split of Groningen and Berlin (Gerike et al., 2020, OIS Groningen, 2023b)

Besides the suburban station Haren, three train stations located in Groningen (see Figure 4). **Groningen Hoofdstation** is the main mobility hub of the city offering national intercity trains to the Randstad, local trains in all directions and a central bus station around which Groningen's bus network is organised. To accommodate for growing numbers of travellers and improve the integration in the city, the station is currently under reconstruction which is planned to be completed in 2026 (Nederlandse Spoorwegen, n.d.). Opened in 2007, **Groningen Europapark** provides a rail connection to the neighbourhoods of Europapark and Helpman. While Helpman is a mostly residential neighbourhood, in Europapark there are many offices and the Euroborg, the home ground of FC Groningen. The station is mostly served by east- and southbound local trains, while some intercity trains stop early in the morning and late at night. **Groningen-Noord** is located between the residential neighbourhoods of Selwerd and Korrewegwijk and is a stop for local trains between Groningen Hoofdstation and Eemshaven/Delfzijl.

Figure 4 - Map of Stations in Groningen (Hausmann, 2024)

2.4.2. Berlin

Berlin is Germany's capital and with about 3.9 million inhabitants more than 16 times more populated than Groningen. With 23 percent, the share of young people below 26 years is

substantially lower than in Groningen (Amt für Statistik Berlin-Brandenburg, 2024). As its districts were only merged into one urban area in 1920, Berlin features a polycentric urban structure. This entails high population densities in the centres of the districts of Mitte, Friedrichshain and Kreuzberg, which are also the destination for many commuting and shopping trips. While central neighbourhoods have shown moderate growth since 2000, the surrounding areas have grown rapidly, which has effects on mobility patterns (Rode et al., 2015). Although cycling traditionally is central to Berlin's transport culture, the mode is not prioritised in urban planning as it is in most of the Netherlands (Rode et al., 2015). With 18 percent, the modal share of cycling is, consequently, significantly lower than in Groningen (see Figure 3). Berlin, however, has a very dense public transport system including trains, trams, buses, light rail (S-Bahn) and metro (U-Bahn), which makes public transport with 37 percent of all trips the most used transport mode. Groningen, on the other hand, only offers a bus network besides its rail connection. With eight percent, only a minority of trips are made using public transport (OIS Groningen, 2023b).

Berlin wants to continue decreasing car traffic by promoting active modes and public transport and therefore increasing safety, accessibility for everyone and environmental sustainability. In its mobility program, the Senate of Berlin outlines its ambition to strengthen the polycentric structure of the city, reduce the consumption of natural resources and space and improve the urban integration of existing infrastructure (Senatsverwaltung Umwelt, Verkehr und Klimaschutz - Abteilung IV - Verkehr, 2021).

The following three stations in Berlin were chosen for the analysis (see Figure 5). Located close to the park Tiergarten in the district Wilmersdorf-Charlottenburg, **Berlin Zoologischer Garten** was the old main station of West Berlin and is nowadays still an important public transport hub offering local train services, light rail, metro, bus and a few long-distance services. With 100,000 passengers per day, it is frequented more than 2.5 times as much as Groningen Hoofdstation (BauInfoPortal, n.d.; OIS Groningen, 2023b). **Berlin-Wannsee** is located about 18 km southwest of Berlin centre in the district of Steglitz-Zehlendorf. It is close to the lake Wannsee on the one side, which is a popular local recreation area and a residential area and is served by light rail, local trains and busses. **Berlin-Schöneweide** is located in the formerly East German district of Treptow-Köpenick about 10 km southeast of the centre, adjacent to a mostly residential area, and is served by light rail, slow local trains, trams and buses.

Figure 3 - Map of Stations in Berlin (Hausmann, 2024)

3. Methodology

A mixed-methods approach was applied to answer the research question and its sub-questions. It was chosen to provide a holistic understanding of the processes discussed in the literature review and to examine links between the quality of cycling-friendly infrastructure at train stations and its actual use. Observations of the built-environment investigate spatial factors, while surveys with train users explore individual factors (see Figure 2).

Three stations in both Groningen and Berlin were determined as case studies. As the urban core of Groningen only has three stations, Hoofdstation, Europapark and Noord, all of them were included in the research. Based on size and type, comparable stations were found in Berlin. Zoologischer Garten was determined as a central transport node comparable in size to Groningen Hoofdstation. Berlin-Wannsee was chosen as an important regional transport stop as a counterpart for Groningen Europapark and Berlin-Schöneweide was as a stop for only local trains chosen as the counterpart for Groningen-Noord.

Observations at the stations investigated to what extent cycling-friendly infrastructure is present, its quality and how well stations are integrated into the local cycling network. As shown in the observation guide (see Appendix A), the infrastructure at and around stations was assessed on a scale from 0 (not present) to 4 (very good). The observation guide is based on the literature review and mostly incorporates factors mentioned by Pucher and Buehler (2012) and Sully (2016). Where evaluation was by definition not possible, e.g., price of e-bikes where no e-bikes are present, '-' shows that the category does not contribute to the overall score. To reduce researcher bias, the categories were divided into between six and eight subcategories to allow grading each as objective as possible. Nevertheless, some degree of personal bias still may have influenced the results. To reduce this, pilot runs were made in both cities and the results were discussed with colleagues afterwards.

A survey was conducted to examine the mode choice and access trip characteristics of people travelling from the investigated train stations (see Appendix B). This method was chosen to investigate mode choices for a broad population as changes in infrastructure change mobility choices on a societal level. The surveys included four questions: the mode choice of the respondent, the decision whether the station is at the home or activity end of the trip, the length of the trip and, finally, which improvements could increase their chance to use the bicycle. People who waited at the platforms were approached and asked to scan a QR code that led to the survey questions. Those who did not want to or could not scan the code were asked to

directly answer the questions. Surveys were carried out between 25 April 2024 and 7 May 2024 in the afternoon during traffic peak hours (4:30 pm – 6:30 pm). Participation in the Erasmus+ programme Sustainable Transformation of Neighbourhoods in Europe (STONIE), in partnership with the Polytechnic University of Milan, Stockholm University and Humboldt University of Berlin, required minor methodological changes. Minor deviations from the stated time were made at the stations Berlin Zoologischer Garten and Berlin-Schöneweide and, at Berlin Zoologischer Garten, the survey was adjusted to include the research of the group in the project.

In line with the GDPR (European Parliament & Council of the European Union, 2016), respondents were informed that participation is voluntary for everyone aged 18 and older, that no private data would be gathered and that participants have the right to withdraw their data from the research at any time. Participants were asked to actively indicate their consent by checking a box before starting the survey while those who answered the survey orally gave verbal consent before responding. The data is stored securely on the researcher's university Google Drive account and will be deleted within two weeks following the completion of the evaluation and from university servers after a retention period of five years.

To ensure comprehensive representation, all people waiting at the platforms were approached and either handed out a QR code or directly asked to participate in the survey. The surveys were translated into German but not into Dutch due to limitations of the researcher. This possibly causes a selection bias towards younger and/or more educated people in the Netherlands, as they are more likely to speak English. Due to limited time, only around 30 responses were gathered at each station suggesting that actual modal splits might deviate from the research results.

4. Results and Discussion

4.1. Observations

4.1.1. Bicycle Parking

Groningen's bicycle parking, already praised by Pucher and Buehler (2012), was more developed than Berlin's (see Table 1). Groningen Hoofdstation and Groningen Europapark offered fully sheltered and guarded cycling garages. In Groningen Hoofdstation, 5,500 of about 10,000 parking spaces are located in the freely usable Stadsbalkon (see Figure 6), where service personnel are present at any time and a roof protects the bicycles from the weather. Adjacent to the platform, bikes can be parked at a guarded parking garage that is only accessible by keycard, thus offering an even higher level of safety. In the same building, a fully functioning bicycle repair shop is located. In Groningen Europapark, the indoor parking garage is freely usable, well-sheltered and guarded at any time during opening hours. There are plenty of parking spots available and the walk to the platform can be, depending on the platform, as short as 40 metres. Limitations are, however, the absence of a repair service beyond simple tools and a bike pump and the opening hours – the parking garage is closed between 2 am and 5 am. However, no trains are scheduled to depart at that time. Groningen-Noord offers about 200 parking spaces sheltered with a simple roof and eight bike lockers to store bicycles. Also, a walk of up to 200 metres is required to reach the platforms.

Figure 6 - Stadsbalkon Bicycle Parking, Groningen Hoofdstation (Hausmann, 2024)

In Berlin, stations mostly featured unsheltered bicycle parking, which demonstrates the comparably low priority of cycling infrastructure in Berlin. Berlin Zoologischer Garten offers, with simple bike racks, only very basic bicycle parking infrastructure (see Figure 7). Besides being neither guarded nor sheltered, the bike racks are located across the street and, therefore, are not easy to reach. As a consequence, many bicycles are left closer to the station's entrance where they are not allowed to be placed. Berlin-Wannsee offers better bicycle parking as more parking spots are available and some parking spots are sheltered. The bicycles were, on a sunny day, crammed under the shelter, showing a high demand for sheltered parking that the station currently cannot meet (see Figure 8). In Berlin-Schöneweide, the main entrance currently cannot be used due to construction works. That is why the provided bicycle parking facilities are sparsely used and instead, bicycles are left at fences or street signs. Among these parking facilities, there is also a two-storey bicycle cage, opened in April 2024, that only customers can enter. It is free of charge, well-sheltered and protects bicycles from theft. Yet, only 1 out of 24 spots was used. In the next years, a two-storey bicycle parking garage including a service station will be built in front of the station, which will improve the parking capacity of the station, demonstrating the increasing significance of bicycle planning in Berlin (infraVelo, n.d.).

Figure 7 - Bike Racks at Berlin Zoologischer Garten (Hausmann, 2024)

Figure 8 - Sheltered Bicycle Parking in Berlin Wannsee (Hausmann, 2024)

4.1.2. Bike-Sharing

At Groningen Hoofdstation, close to the guarded parking garage, there are 1000 OV-bikes for rent. The price is 4.55 €/day, however, for people with a Dutch public transport subscription it is free. Those bicycles are integrated into the NS app and are checked for damages every time they are rented out. The same applies to Groningen Europapark. However, only 2 out of 20 bicycles and no e-bikes were available during the observation meaning that one cannot reliably plan the egress trip from Groningen Europapark with a shared bike. In Groningen-Noord, ten bicycles were available, but there they are not always checked for damage.

Zoologischer Garten offers several shared bicycles and shared e-bikes. However, these are in a worse state than the Dutch OV-bikes and the German call-a-bike system is also not as customer-friendly in mobile app integration as a second app has to be installed to rent a call-a-bike bicycle. Depending on subscription type, prices can be lower compared to OV-bike but they are not included in the public transport subscription. At Berlin-Wannsee and Berlin-Schöneweide, there were no shared bikes available.

4.1.3. Urban Integration

Groningen Hoofdstation is well-integrated into the urban cycling network – a cycling path even leads through the Stadsbalkon. However, signs to and from parking facilities are sparse and leaving the station to the south is also difficult. With the completion of the reconstruction, this will be improved by the provision of a bicycle tunnel under the platforms. Groningen Europapark is likewise very well integrated into the cycling network. There is a wide cycling tunnel leading through the station and directly to the bicycle garage (see Figure 9). In the surroundings, all cycling paths are physically separated from car traffic, equipped with streetlights and rarely give cyclists the need to stop. The integration of Groningen-Noord, on the other hand, is not optimal. While there is one (in parts) physically separated cycling path connecting the station with Groningen's centre, many paths share the road with cars without physical separation. Furthermore, close to the parking facility, there is only a limited number of streetlights and signage available.

Figure 9 - Bicycle Tunnel at Groningen Europapark (Hausmann, 2024)

At Berlin Zoologischer Garten, the cycling network surrounding the station is very limited. There are a few on-street cycling lanes that are not physically separated from car traffic and are often poorly signed. Cyclists were not given a high priority while planning the space around Zoologischer Garten. Similar trends were observed around the stations of Wannsee and Schöneweide. While both stations' parking facilities could not be reached by bike without violating traffic regulations and interfering with pedestrians, both could at least offer some physically separated cycling paths while lighting at Berlin-Wannsee was slightly better than at the other stations.

Table 1 - Results Observations

	Groningen			Berlin		
Criteria	**Hoofdstation**	**Europapark**	**Noord**	**Zoo**	**Wannsee**	**Schöneweide**
Bicycle Parking	**3.9**	**3.6**	**2.1**	**0.6**	**1.2**	**1.6**
Sufficiently Available	4	4	3	1	2	1
Accessible from Platform	4	4	2	2	2	1
Sheltered (Free)	4	4	2	0	2	0
Sheltered (Paid)	4	4	3	-	-	3
Guarded	4	4	2	0	0	2
Opening times	4	3	-	-	-	-
Price (If Guarded)	3	4	3	-	-	4
Bike Stations	4	2	0	0	0	0
Bike Sharing	**4.0**	**2.3**	**2.5**	**1.8**	**0**	**0**
Sufficient Available	4	1	2	2	0	0
Public Available	4	1	2	2	0	0
E-Bikes Available	4	0	0	3	0	0
App Integration	4	4	4	1	-	-
State of Bicycles	4	4	3	2	-	-
Price	4	4	4	1	-	-
Urban Integration	**3.4**	**4.0**	**2.7**	**1.6**	**1.7**	**1.4**
Network Density	4	4	3	3	3	2
All Directions	2	4	3	2	2	2
Legally Reachable	4	4	4	2	1	1
Signposting	2	4	2	1	1	1
Physically Seperated	4	4	2	0	1	1
Streetlights Available	4	4	2	2	3	2
Waiting at Junctions	4	4	3	1	1	1

4.1.4. Desired Infrastructural Changes

Figure 10 shows which infrastructural improvements travellers at the six stations would like to see implemented to increase their likelihood of using the bicycle. It is apparent that more changes to cycling-friendly infrastructure in and around stations are demanded in Berlin. Generally, changes to parking were the most desired, improvements in urban integration the second and improved bike-sharing the least. Only in Groningen Hoofdstation, interestingly the station with the best bike-sharing, improvements in bike-sharing had the highest priority. This can be explained either, following Fosgerau et al. (2022), by induced demand for bike-sharing or by a lack of awareness. Increased awareness, e.g., induced by public advertising, can therefore increase the usage of bike-sharing services. Particularly regarding the cycling network, respondents in Berlin were more eager to see improvements than in Groningen, which is expected, as Groningen has the reputation of being a cycling city, which, in the last decades, prioritised the bicycle in its urban planning.

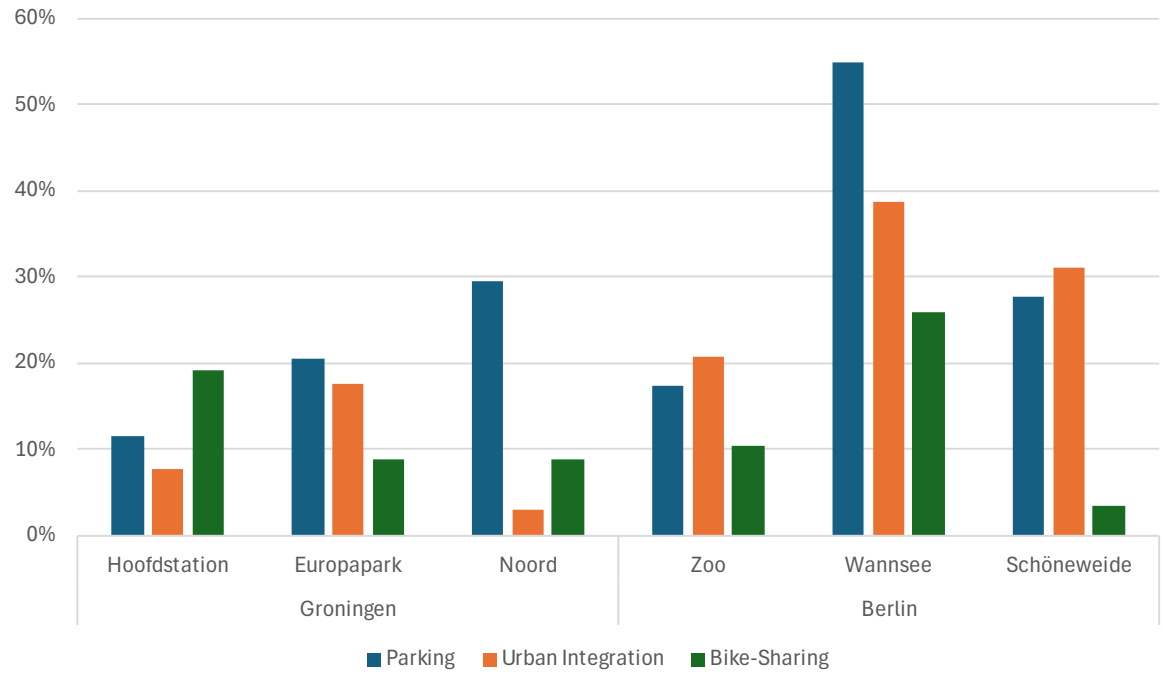

Figure 10 - Desired Infrastructural Changes in Groningen and Berlin (Hausmann, 2024)

In Groningen Hoofdstation and Berlin Zoologischer Garten, the least changes were demanded, which can be explained by the better integration with public transport compared to other stations. This, on the one hand, increases the catchment area beyond what is feasible to cycle and, on the other hand, gives viable alternatives to the bicycle for moderately long trips (1-5 km).

4.1.5. Comparison Groningen – Berlin

As shown in Table 1, according to the factors distinguished in the literature review, the integration of cycling-friendly infrastructure proves to be better in Groningen than in Berlin. Although Groningen-Noord in almost all dimensions came off worse than the other stations, its cycling integration still surpasses that of stations investigated in Berlin in all dimensions. There seems to be great potential for improved bike-sharing in Europapark and Noord as the number of available shared bicycles was too low to reliably plan the multimodal journey. Groningen Europapark and Groningen Hoofdstation, particularly once all construction is done, can be seen as great examples and role models of high-quality bicycle integration for urban train stations.

While in Groningen one common design for bicycle infrastructure is used to maximise efficiency, the design varies in Berlin from station to station, suggesting that cycling infrastructure has not matured in Berlin as it has in Groningen. In Berlin, the results are generally less positive. Bicycle infrastructure was often very basic or not present, as indicated in Table 1 by the number 0. Particularly, Zoologischer Garten offered very poor parking infrastructure, while the other two stations did not offer any shared bikes. Urban integration is not very good in any of the stations in Berlin and, generally, the whole cycling network in Berlin appears to be less developed than in Groningen.

4.2. Influence on Mode Choice

As shown in Figure 11, the modal share of cycling differs between Groningen and Berlin. The highest share observed in Berlin is only one-third of the lowest share in Groningen. On the one hand, this can be explained by the better provision of cycling-friendly infrastructure at stations in Groningen. Yet, only a co-occurrence of infrastructure and a high share of cycling is shown, but no causality. Following Fosgerau et al. (2023), a causal relationship would be logical following the theory of induced demand. Good cycling infrastructure and a high cycling share, could also both be symptoms of a flourishing cycling culture as explained by Kager & Harms (2017) and therefore be caused by positive attitudes about cycling in the population. This idea is supported by the high share of cycling to the station Groningen-Noord, despite having worse cycling infrastructure than Groningen's other stations. Nevertheless, even if there is no (or only a weak) direct causal link between the provision of infrastructure and the modal share, actively used cycling infrastructure can contribute to strengthening cycling culture and, therefore, holds the potential to change the modal share of cycling in the future (De Groot, 2016).

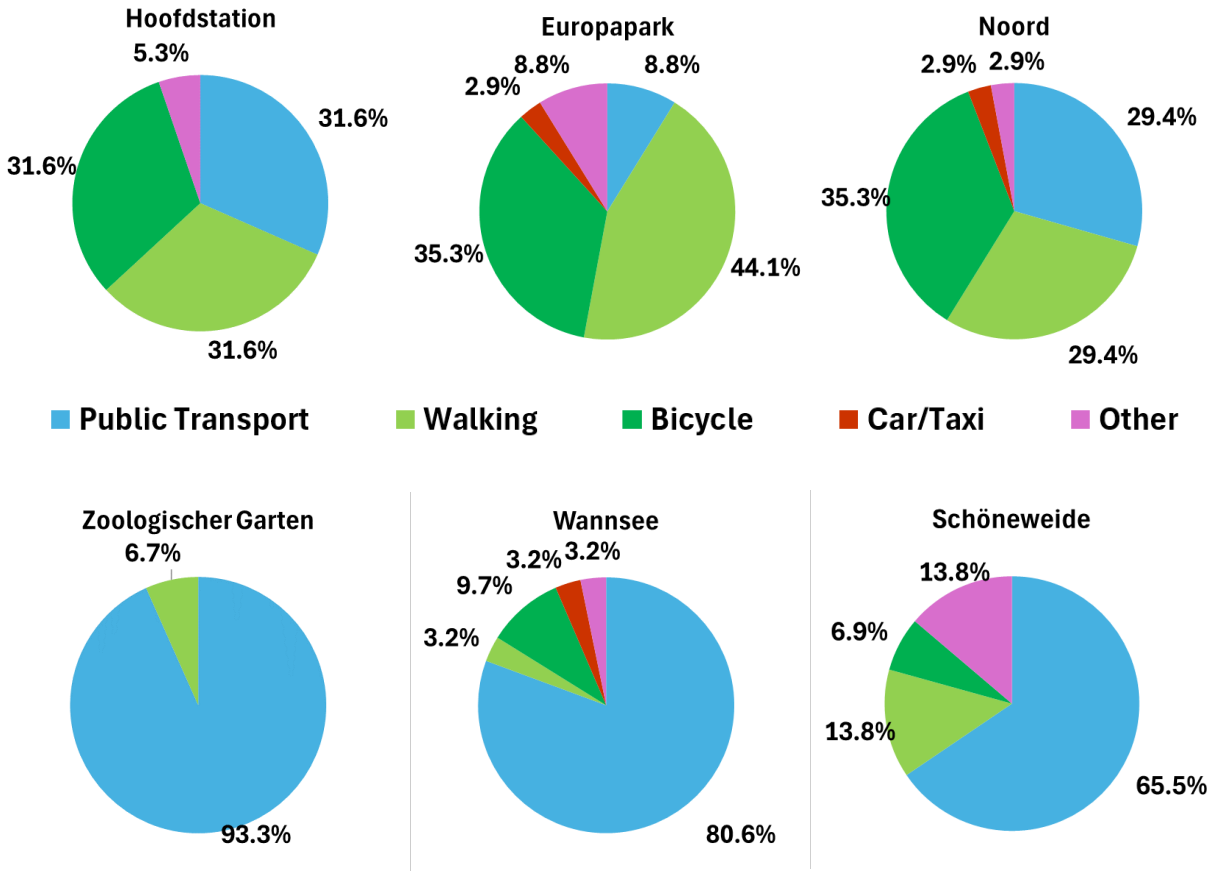

Figure 11 - Access Trip Modal Split for Stations in Groningen and Berlin (Hausmann, 2024)

On the other hand, the differences between Groningen and Berlin can be explained by different urban settings. It can be a consequence of the provision of a good public transport network in Berlin – or the underprovision of public transport in Groningen. Furthermore, walking is significantly more popular in Groningen than in Berlin. This increased share of active modes can also be explained by Groningen's concentrated structure of a compact city, which shortens distances. It can be assumed that most of the trips done walking or cycling in Groningen are done by public transport in Berlin. However, because of the symbiotic effects of cycling and public transport (Kager, Bertolini & Te Brömmelstroet, 2016), integrating these modes into urban mobility policy is recommended for making mobility more sustainable. In central hubs, such as Berlin Zoologischer Garten, a high share of public transport is expected because of its relevance as a changing station for local public transport modes with a large catchment area. While the station's cycling infrastructure, particularly its parking, should still be improved, changes in the modal share of access trips will be larger in smaller stations such as Wannsee or Schöneweide.

5. Conclusion

This research investigated bike-train integration through cycling-friendly infrastructure in Groningen and Berlin. A mixed-methods approach consisting of observations and surveys was used at six stations to evaluate the presence and quality of cycling infrastructure and its effects in influencing the share of access trips using the bicycle.

The findings show that in almost all dimensions Groningen's cycling infrastructure around stations surpasses Berlin's. Particularly Groningen Hoofdstation and Groningen Europapark offer a high level of cycling integration, characterised by good bicycle parking, bike-sharing and urban integration. Despite Groningen-Noord's lower infrastructural quality, it still surpasses all of Berlin's stations in every dimension. Cycling infrastructure around Berlin's station is less developed, typically showcased by a lack of cycling paths that are physically separated from car traffic, rudimentary parking facilities and absent bike-sharing. Particularly Berlin Zoologischer Garten provided a very basic bicycle infrastructure reflecting the historically lower priority of cycling in urban planning in Berlin compared to Groningen. Similarly, in Berlin-Wannsee and Berlin-Schöneweide, the lack of bike-sharing services shows missed opportunities in multimodal transportation.

Recent developments, such as a planned two-storey bicycle garage in Berlin-Schöneweide, suggest a growing recognition of the importance of cycling in urban planning in Berlin. In Groningen, the cycling-friendly reconstruction of the central station demonstrates the city's commitment to further improving cycling infrastructure. This will enhance both cities' multimodal transport and make their mobility more sustainable, whereas possible drawbacks for other users of the transport system and public space have to be considered.

While no causation could be determined, the modal split analysis shows a co-occurrence of a high share of cycling and good infrastructural integration of bike and rail. That shows that there are links between the spatial components, bike parking, bike-sharing and urban integration, and individual travel decisions as proposed in the theoretical framework. In Berlin, most people use local public transport to access trains, while in Groningen, cycling and walking are used most often. This is either the consequence of induced demand or of the strengthened bicycle culture caused by improved bike and rail integration.

Future research could further investigate the differences and similarities of the effects of induced demand compared to enhanced cycling culture. Furthermore, more cities that offer high-quality bike-rail integration could be compared to determine best practices.

In summary, the study shows the importance of high-quality, well-integrated cycling infrastructure in promoting bicycle use among train commuters. Groningen's advanced infrastructure and strong cycling culture offer valuable lessons for Berlin, which, despite its current shortcomings, shows potential for improvement. Investing in comprehensive cycling facilities and fostering a cycling-friendly environment can lead to increased numbers of cyclists, contributing to more sustainable urban mobility.

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Appendix A – Observation Guide

Bicycle Parking

Is a sufficient number of parking spaces available?	0 1 2 3 4
Is the platform easily accessible from the bicycle parking?	0 1 2 3 4
How is free bicycle parking sheltered?	0 1 2 3 4
How is paid bicycle parking sheltered?	0 1 2 3 4
How is the price for paid bicycle parking?	0 1 2 3 4
How is bicycle parking guarded?	0 1 2 3 4
If guarded by a person, how user-friendly are the opening hours?	0 1 2 3 4
Are there bike stations available in the surrounding?	0 1 2 3 4

Bike-Sharing

Are sufficient shared bikes available?	0 1 2 3 4
Are sufficient public shared bikes available?	0 1 2 3 4
Are sufficient e-bikes available?	0 1 2 3 4
How well are bike-sharing integrated in public transport apps?	0 1 2 3 4
What is the state of the shared bicycles?	0 1 2 3 4
What is the price?	0 1 2 3 4

Urban Integration

How dense is the cycling network around the station?	0 1 2 3 4
Do cycling paths lead from the station in all directions?	0 1 2 3 4
Are parking facilities reachable without violating against traffic rules?	0 1 2 3 4
Is signposting available to guide towards and from parking facility?	0 1 2 3 4
Are cycling paths physically separated from car traffic?	0 1 2 3 4
Are streetlights available?	0 1 2 3 4
Are cyclists given priority at junctions?	0 1 2 3 4

Appendix B – Survey

This survey is part of the Bachelor Thesis "Multimodal Transport for Sustainable Cities – Comparing the Integration of Public Transport and Cycling in Groningen and Berlin".
By answering the survey you agree to the use of your provided data for university research purposes. Only people aged 18 and older are allowed to participate. No sensitive or personal data will be gathered and all gathered data will be deleted upon completion of the project. If you have any more questions or wish to withdraw your data from the study after sending in this form, please reach out to me via E-Mail: (j.hausmann@student.rug.nl).
Thanks for your participation!
Jakob Hausmann

Which mode of transport did you use today to get to [station]

- Local Public Transport (not train)
- Bicycle
- Walking
- Car/Taxi
- Other
- (I'm Changing Trains)

How far do you estimate was the distance you travelled to the station

- <1km
- 1-3km
- 3-5km
- 5-10km
- >10km

Was [station] the home end or activity end of your journey

- Home End
- Activity End
- (Changing Trains)

What interventions could increase the likelihood of you reaching the station by bicycle?

- Improvements Parking Facilities
- Improvements Bike-Sharing
- Improved Cycling Network
- Other: