# NaMikro

## Sustainable Micro Mobility

Investigation into the sustainable use of sharing services as an extension of local public transport in city outskirts and small municipalities

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Version 1.0

Technische Hochschule Wildau
Hochschulring 1
15475 Wildau
Contact:
Prof. Dr.-Ing. Christian Rudolph
Nicolas Schüte

The research project was conducted in cooperation with the research partner Bolt Technology OÜ (Vana-Lõuna tn 15 Tallinn 10134 Estonia).

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| Remark | For reasons of better readability, the simultaneous use of female and male language forms is generally omitted. All personal designations nevertheless apply to both genders. |

# Table of Contents

# 1. Executive Summary

Shared micro mobility hire systems have already been established in a large number of German cities for several years. While it has already been possible to gain insights into the use of these systems, particularly in inner-city areas and large cities, there is still a lack of fundamental scientific studies investigating the use of shared micro mobility in small towns and on the outskirts of cities. One of the most important questions is the extent to which usage behavior in small towns and suburban areas differs from that in city centers and whether sharing services are used outside large cities and city centers as a possible feeder and supplement to public transport. Other questions often asked by local authorities and transport planners include the extent to which car journeys can be substituted by sharing services and the economic viability of operating shared micro mobility in less densely populated districts. This report therefore focuses primarily on how e-scooters and e-bikes can be used in sharing systems in suburban areas and small towns as an extension of public transport. Different price and status models and the use of different vehicle types were analyzed as fundamental factors influencing the operation of sharing services. The study took place in three test areas (so-called real-world laboratories), where different charging and pricing models were introduced with the aim of making the combination of the sharing system and public transport as attractive as possible. The real-world labs were carried out from summer 2022 to spring 2023 in Berlin-Lichtenrade, Berlin-Zehlendorf and the city of Erkner, each with half of the e-scooters and half of the e-bikes. The pricing models tested included per-minute prices well below the usual market prices. Concepts with a doubling of the price per minute from the 13th minute of rental at standard market prices per minute were also examined and an incentive model was analyzed which credits the user with free minutes if the sharing vehicle is returned in the immediate vicinity of a train station. There were also three different drop-off models: the classic free-floating model where the vehicle could be dropped off anywhere, a concept with purely virtual drop-off stations that were only visible in the cell phone app and a concept with colored drop-off areas marked on the ground.

The investigations were supplemented by analyses of usage data from the core area of Berlin and surveys of users in the real-world laboratories. In addition, expert interviews were conducted with representatives of the public authorities of the participating local authorities and with representatives of the provider side.

Based on the analysis, the TH Wildau has come to the following conclusions:

- E-scooters are clearly favored over e-bikes. The proportion of rented vehicles and the results of the surveys clearly show this. This must be taken into account when designing sharing systems. Nevertheless, there is also a smaller group that favors e-bikes. The different preferences must be taken into account through a targeted fleet composition.
- Overall, there is great potential to replace short car journeys with sharing systems, even in suburban areas, and to replace longer car journeys through an intermodal combination of sharing systems in conjunction with public transport. In this way, shared micro mobility can further strengthen the environmental network and contribute to achieving ambitious emission-reduction goals. Sharing systems can make a valuable contribution as an extension to public transport, particularly at times of day when public transport services (especially bus services) are thinned out. However, due to the low population density, sharing providers have to reckon with reduced economic viability of operations. This results in the task for the

participating municipalities and providers to jointly develop a solution for an economically viable operation. Here, for example, a subsidy from the municipality or the development of new concepts could be an option.
- Virtual drop-off stations are inadequate from the point of view of all stakeholders surveyed due to the inaccuracy of GPS technology. As a result, the in-app parking areas have to be significantly larger than intended. In addition, customers are unsure where to park since there are no physical markings with which to orient themselves. Fixed parking areas, which were labeled with yellow markings in a real-world laboratory, help users significantly, but must be dimensioned in such a way that a sufficiently large area is available. The spaces must be large enough, especially at high-demand stations such as S-Bahn train stations. Overall, it has been demonstrated that a station-based system is just as well accepted under certain conditions as a free-floating system, for example. Weighing up the interests and demands of all stakeholders, operation in a high-density station-based system has proven to be the most promising solution in terms of high compatibility in public spaces. Preferably, the stations should be planned on the side of the street, not on the sidewalk.
- Steering users via monetary incentives (push and pull) has virtually no measurable effect on the choice of transport mode. In addition, it has been shown that the introduction of a sharing system can work at normal market prices on the outskirts of the city. Even realized price increases have not led to a decrease in demand, which indicates that customers in municipalities with a reduced public transport offer are willing to pay market prices.
- Certain guidelines for an ideal-typical design of a sharing system can be drawn from the results. However, the design of a sharing system is ultimately individual and must be customized for each municipality. What is important here is close and early coordination between the provider and the municipality as well as carefully prepared communication in order to ensure acceptance of the system.
- In the medium term, sharing systems should be better integrated into existing transport planning and the existing transport system than they have been, in order to fulfill the potential of intermodal use and to increase the currently still low level of acceptance among parts of the population (primarily non-users) due to sharing vehicles being parked in violation of regulations.

# 2. Introduction

## 2.1.Motivation and research question

Providers of e-scooter, e-bike or e-moped sharing services are now active around the world with their micro mobility services. The small and light electric vehicles are clearly superior to cars in terms of energy and space efficiency across short distances. If the electricity for these vehicles is generated using renewable energies, users are virtually $CO_2$-neutral while travelling. This means that every trip in the micro area that replaces a car journey should be viewed positively from a transport science perspective. Motorized private transport notoriously suffers from high levels of congestion, especially in large cities (see Falck & Wölfl, 2023), and the number of residents affected is particularly high. Sharing vehicles can also serve to feed local public transport when looking at the so-called first and last mile. The free-floating system currently being used offers a convenient mobility service (provided that the vehicles are readily available). This is because the vehicles can be parked nearly anywhere as long as they do not interfere with the flow of motorized traffic, cyclists or pedestrians.

The Ordinance on Small Electric Vehicles (eKFV), which came into force on June 6, 2019, has set the regulatory framework for the use of electrically powered small vehicles (e-scooters) in public (road) spaces. As a result, various private-sector mobility providers with flexible rental offers (sharing mobility) have initially been increasingly launched in city centers and large cities (Levin-Keitel et al., 2022). In the meantime, providers have been developing many small towns and suburbs of large cities. In general, these urban areas have a different structure in terms of local public transport, both in terms of space and time. Accordingly, the density and frequency of public transport services on city outskirts are comparatively lower than in inner-city areas (Ahrens et al. 2010). The “ÖV-Atlas Deutschland 2022” (2022 Public Transport Atlas for Germany) shows the difference between large and small cities based on a nationwide categorization of public transport density according to various key figures. For example, the city of Berlin has a density of 1,546 trips per km², whereas the small town of Erkner in Brandenburg, bordering Berlin directly, only has a density of 458 trips per km² (Agora Verkehrswende, 2022). On the other hand, Berlin's outer districts have a higher average private car density per capita than inner-city districts (AfS, 2021).

Various studies have shown that short distances that are usually covered by car can be substituted with vehicles from the micro mobility sector, thus especially reducing traffic congestion (cf. Fan & Harper, 2022; Asensio et al., 2022). The potential of sharing services as a sustainable means of transportation in intermodal travel chains tends to be seen more in metropolitan suburbs and neighboring municipalities (see Levin-Keitel et al., 2022). According to a Germany-wide study on e-scooter use by Allgemeiner Deutscher Automobil-Club e. V. (ADAC), roughly 50% of users stated they use e-scooters as a supplement or feeder to public transport. According to this survey, a third use it as an alternative means of transport if public transport is too full and 18% as a feeder to the nearest public transport station. For 7%, alternative use to public transport is even the main reason for using e-scooters (see ADAC, 2023a). The administration of the Berlin Senate has formulated the objective of increasingly shifting sharing services to areas of the city outside the S-Bahn ring (inner-city train ring) and providing appropriate incentives, such as exemption from special usage fees (see SenMVKU, 2022).

The "NaMikro - Sustainable Micro Mobility" research project addresses this starting point. The project study primarily addresses the framework conditions under which a sharing service consisting of e-scooters and e-bikes can be used on the outskirts of Berlin as a supplement to existing public transport and as a feeder to the S-Bahn train service. The focus here is on the appropriate design of the service and findings on other user preferences. For example, it will be examined which type of vehicle (e-scooter or e-bike) is preferred and for what reasons. In addition, the extent to which car journeys can be replaced on shorter routes will be investigated in order to be able to clearly assign sharing services to the environmental network. Initial studies also show that a proportion of the journeys made with rental scooters would otherwise have been made using eco-mobility, i.e. on foot, by bike, or by public transport (see Agora Verkehrswende, 2019; ADAC, 2023a). This results in so-called cannibalization effects within the environmental network. However, other studies also show that, despite these cannibalization effects, e-scooter sharing systems contribute to reducing $CO_2$ in most cases. This is because other modes of transport are also replaced that cause significantly higher $CO_2$ emissions, such as private car use (cf. Krauss et al., 2022; EIT InnoEnergy, 2022).

This project investigates whether the density of use in suburban locations is at least as high as in inner-city locations in terms of average use, as there is a corresponding demand for shared mobility in the form of e-scooters and e-bikes due to the lack of public mobility services. Against this background, the aim is to investigate how users can be financially managed or incentivized and under what conditions the economic viability of the sharing service can be guaranteed. It will also be examined whether the reduced urban area means that the distances between the origin and destination are shorter, making intermodal use (with public transport) unnecessary for certain journeys.

The topical discussion in the media and examples from other countries show how controversial the topic of shared micro mobility is. Among the population, the problems of the sharing system, in particular the incorrect parking of vehicles, have led to a contrasting perception of this still comparatively new mobility service. While 30% in a survey conducted by the ADAC in Germany assume a negative image, 16% ascribe a positive image to e-scooters (ADAC, 2023a). Providers are therefore dependent on good cooperation with local authorities and the population in order to achieve the highest possible acceptance of their offer and to develop solutions for systemic problems together with local authorities. The launch phase in particular, when expanding the existing business area or starting a new business area (island location), can be crucial for providers with regard to the acceptance of the affected stakeholders. If there is no prior knowledge or experience in dealing with the sharing systems and the surrounding services, this can trigger a controversial discussion.

The project therefore introduces various station systems and examines their acceptance among users and their impact on traffic:

In the so-called free-floating system, sharing vehicles can be borrowed and parked anywhere within a defined business area after use. The condition for parking is that the vehicles do not interfere with other road users. However, this concept involves risk due to carelessly parked sharing vehicles. For example, some vehicles are parked in violation of the rules, topple over onto their side, so that they obstruct pedestrian traffic and can also be a nuisance for cyclists and motor vehicles as well as other users of sharing services (Difu, 2022). In order to better regulate parking, there are various ideas and concepts for station-based systems, such as markings on the ground or geofencing.

However, the anticipated potential currently still faces a number of conflicts. In Paris, for example, the public rental of e-scooters has been banned since September 1, 2023 following a referendum. The example of the French capital shows that even supposedly sustainable mobility offers can disappear from the range of services due to inadequate regulation coupled with disregarded etiquette on the part of users (see FAZ, 2023). This is despite the fact that the use of shared micro mobility has been shown to have a high $CO_2$ reduction potential, particularly in Paris (Krauss et al., 2022). In addition to bans, over-regulation can of course also lead to private sector players withdrawing from markets or not offering their services (cf. Schimroszik, 2022).

These practical examples clearly show that a holistic approach involving all relevant stakeholders is necessary in order to reduce conflicts, avoid withdrawals and bans and leverage the existing potential of sharing services as a sustainable means of transportation. When implementing a sharing service, the main stakeholder groups must be taken into account: Users of the sharing service and other road users (e.g. pedestrians, cyclists), residents, the sharing service providers and the municipalities in which the service is provided and used (see Difu, 2022).  From a municipal perspective, the main issue is whether the municipality wants to play an active or passive role in the operation and design of the sharing system. Active participation would not only consist of supporting the offer (pull measures), but would also make the use of private cars unattractive through accompanying interventions (push measures). A combination of push and pull measures is considered fundamental in order to raise the attractiveness of shared micro mobility (cf. Gersch et al., 2021).

Image 1: E-scooters in sharing mode (source: Bolt)

## 2.2.Real-world laboratory: NaMikro

In the "NaMikro - Sustainable Micro Mobility" project, insights were gained into user behavior after the launch of a new sharing service under varying framework conditions. The aim was to develop innovative solutions to better link the rental services with public transport. To this end, different operating approaches were tested and examined within a comparable period of time in comparable urban areas with local differences in important parameters. Against this backdrop, the real-world laboratory method was chosen, which enables close cooperation between research, mobility providers and the public sector in order to study the reactions of users. According to Schneidewind (2014), real-world laboratories are defined as follows:

> ***"A real-world laboratory refers to a social context in which researchers carry out interventions in the sense of 'real experiments' in order to learn about social dynamics and processes. The idea of the real-world laboratory transfers the scientific laboratory concept to the analysis of social and political processes. It ties in with the experimental turn in the social and economic sciences. There are close links to concepts of field and action research"*** **(Schneidewind, 2014).**

By bringing together different stakeholders (providers, users, administrations, research), it is possible to investigate what solution-oriented measures could look like (cf. Gantert & Stokman, 2018). Corresponding solutions appear to be particularly important in the network of effects of sharing offers in the field of micro mobility in order to be able to overcome obstacles and barriers that currently stand in the way of practical implementation (see Chapter 3.1).

In such an experimental environment, questions relevant to transport science can be answered under real conditions by testing innovations in the field of mobility in the real-world laboratories and then evaluating and classifying them. At best, the tested mobility solution and the recommendations for action derived from it can serve as a conceptual template for sustainable mobility in the future (cf. DLR, 2023).

While sharing services in Germany were mainly a big-city phenomenon, especially in the early years, they have also become increasingly established in small and medium-sized cities such as Merseburg (Saxony-Anhalt), Stein (Bavaria) and Laatzen (Lower Saxony) over the past two years. This has allowed providers and local authorities to gain initial operation experience in such cities, although this has not been scientifically proven or monitored. Against this background and in order to investigate the following hypothesis, three real-world laboratories were therefore implemented.

The project was carried out by the mobility service provider Bolt Technology OÜ in cooperation with the BMDV endowed professorship "Cycling in intermodal transport networks" at Wildau University of Applied Sciences (TH Wildau). Bolt was responsible for setting up and operating the real-world laboratories, while TH Wildau provided scientific support. To study the various constellations, three new test areas were designed in and around Berlin, on the outskirts of the city, which were not previously part of the business area of sharing providers.

## 2.3.Hypotheses

The following hypotheses were developed on the basis of the motivation just explained and the research questions formulated. Hypothesis 1 is based on the time advantage that bicycles and e-scooters have over motor vehicles on short trips. This is due to the fact that no parking spaces need to be found and the higher maximum speed of motor vehicles is usually more than compensated for by stopping at traffic lights and/or traffic jams. If a sharing system is offered for the “last mile”, eco-mobility (walking, cycling, public transport) can serve as an attractive alternative to a car.

**Thesis 1: Sharing systems offer great potential for shifting short trips from cars to e-scooters and e-bikes.**

Compared to inner-city areas, areas on city outskirts generally have a lower density and frequency of public transport (see Chapter 2.13.1). This suggests that the integration of sharing systems can compensate for local deficits. This leads to the following thesis:

**Thesis 2: Sharing services can significantly increase the catchment area and the attractiveness of public transport, especially in suburban locations and small municipalities with limited public transport services.**

Due to the potential to supplement the comparatively underdeveloped public transport system on city outskirts, it may also be assumed that the density of use will be correspondingly high as a result. The third thesis is as follows:

**Thesis 3: Particularly in the outskirts of large cities, the density of use in terms of average vehicle use is at least as high as in city-center locations, as there is a corresponding demand for rental systems due to the lack of public mobility services.**

In addition to the generally expected demand for use as a supplement to public transport, the feeder function of the sharing systems to public transport should also be examined. In line with the second thesis, the link to the S-Bahn train system in particular should be considered here, as this is the fastest public transport connection in the real-world laboratories to the city center and is therefore most likely to increase the catchment area. The thesis here is as follows:

**Thesis 4: Different pricing models (e.g. incentives for returns near a station) and different station concepts (e.g. free floating vs. fixed stations) lead to a shift towards a combination of sharing and public transport.**

Finally, the question remains as to how users can be addressed and activated most effectively alongside various pricing and station systems. The vehicle used appears to be key here. It is assumed here that users are not indifferent in their choice between e-scooters and e-bikes. This thesis follows from this:

**Thesis 5: E-scooters appeal to people for whom a bicycle or e-bike is out of the question.**

This report summarizes the most important findings from the NaMikro research project. The following chapter first explains the methodology of the project and then goes on to discuss the resulting findings. In summary, recommendations for action for the preparation, implementation and operation of sharing services on the outskirts of cities and in small towns are derived from all the findings of the project. The focus here is on taking into account the usage requirements of the rental system as well as the opportunities and barriers to implementation for providers and local authorities.

## 2.4.BOLT background

Bolt, founded in Estonia in 2013, is a European mobility platform that has set itself the goal of making urban mobility more affordable, safer, and more sustainable.

Around 100 million customers use Bolt’s services in 45 countries and over 400 cities in Europe and Africa. The company aims to accelerate the transition from owned cars to shared mobility and offers alternatives for every use case, including taxi and car rental services, e-scooters and car sharing as well as food and grocery deliveries. Bolt has been active in Germany since May 2021 and will be offering e-scooters for rent in 69 cities in Germany and e-bikes in 8 cities by the end of 2023.

## 2.5.Background to the BMDV Endowed Professorship for Cycling in Intermodal Transport Networks at TH Wildau

The BMDV Endowed Professorship of Cycling in Intermodal Transport Networks at the TH Wildau uses innovative teaching and learning methods to train cycling planners explicitly for the Mobility Transition in Germany's first master’s degree in Cycling Planning: “Master's Degree in Cycling in Intermodal Transport Networks” (M.Eng.). In application-oriented research projects on cycling, in particular on the topics of safety, intermodality and commercial cargo bike use, the professorship is actively involved in shaping the mobility transition. The employees are very well integrated into the cycling community via the network of the seven BMDV endowed professorships for cycling. There are also particularly good contacts with the scientific players involved in last-mile logistics using cargo bikes. For example, the “Radlogistik 2023” sector report was published under the scientific supervision of Radlogistikverband Deutschland e.V. (RLVD) by TH Wildau. The professorship also has an innovatively equipped bicycle traffic laboratory at its disposal, which is equipped with state-of-the-art recording and survey technologies. It is set to develop into a center for bicycle traffic data in parallel.

# 3. Methodology

The methodological approaches used for the study are described below. The concept and the actual real-world laboratories implemented are described by way of introduction. This is followed by an explanation of the pricing and station systems and vehicle fleets studied, as well as the survey of parking violations. Due to the diversity of actors already explained, various methods are used to obtain the data relevant to the project. To evaluate the use of sharing services in the real-world laboratories, the relevant data is analyzed anonymously. In addition, the users are surveyed to obtain necessary findings that cannot be derived from this data alone or otherwise could only be assumed. Expert interviews are conducted with representatives of municipalities and providers so that further stakeholder-specific expertise can be incorporated into this study.

## 3.1. Design of the real-word laboratories

The purpose of testing different real-world laboratories is to test and scientifically monitor the launch of sharing services in different spatial structures on the city outskirts. Areas on the outskirts of a large city are not homogeneous. For this reason, three different spatial structures in terms of population, car and public transport density were identified as business areas for the research project. Two areas in different suburbs of Berlin (Zehlendorf in the Steglitz-Zehlendorf district and Lichtenrade in the Tempelhof-Schöneberg district) were used as well as the small town of Erkner which borders Berlin. This allowed different spatial structures to be taken into account. The selection of three different real-world labs allowed for a direct comparison of different pricing and station systems

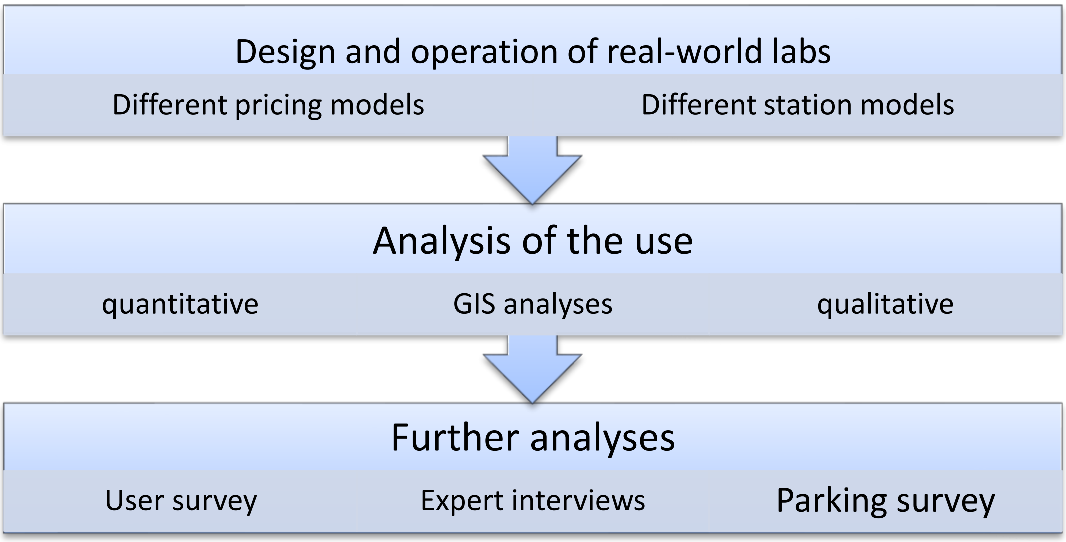

Image 2: Diagram of the methodological approach

The real-world laboratories in Lichtenrade and Zehlendorf were run for around 10.5 months (July 2022 to May 2023). In Erkner, the duration of the real-world lab was instead shortened to roughly 8.5 months (September 2022 to May 2023), as there was a greater need for coordination between the stakeholders in advance.

## 3.2.Description of the real-world laboratories

The fact that Bolt's warehouse (workshop, vehicle depot, etc.) is located in Berlin-Lichtenrade (see Image 3) was a decisive factor in the design of the real-world laboratories in the south and south-west of Berlin. Hereby, the distance traveled to the real-world laboratories (e.g. to replace batteries) was reduced. The provider was thus able to save on the costs of long trips. The real-world lab in Erkner, on the other hand, meant significantly longer journeys for the supplier, so that a comparative analysis of the influence of the distance from the warehouse to the business area on the operating costs and the resulting need for action was possible.

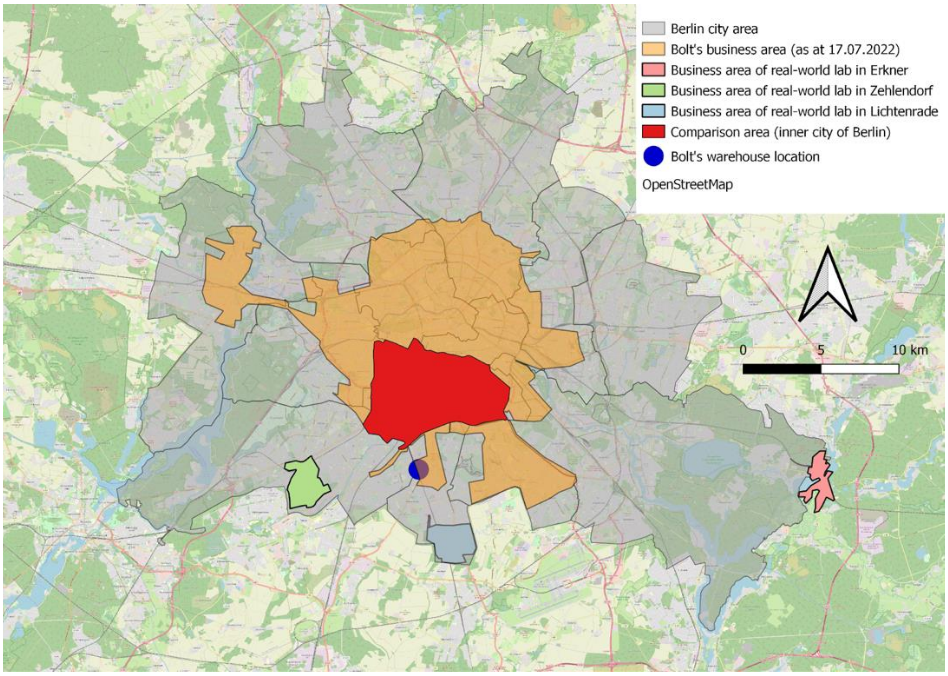

Image 3: Location of the real-world labs in and around Berlin

In terms of area types, Erkner can be classified as an "urban area in a metropolitan city region" according to the regional statistical spatial typology for mobility and transport research (RegioStaR) of the Federal Ministry for Digital and Transport (BMDV). The real-world laboratories in Berlin can be classified as a "metropolis" (BMDV, 2020).

Table 1: Overview of the real-world labs (own presentation based on AfS, 2023; Agora Verkehrswende, 2022)

| **Real-world lab** | **Population density [inhabitants/km$^2$]** | **Car density (private) [per 100,000 inh.]** | **Public transport density [freq. in min.]** | **Area [km$^2$]** |
|---|---|---|---|---|
| Erkner | 716 | 513 | 30 | 3.9 |
| Lichtenrade | 5,205 | 300 | 10 | 5.9 |
| Zehlendorf | 2,918 | 380 | 10 | 6.1 |

The two Berlin laboratories are differentiated on the basis of the parameters of population density, private car density, public transport density and area (see Table 1). The differences in population density and car density are important key figures that will be used to analyze the findings in the remainder of this report. Thus, despite a uniform overarching area categorization, there are local differences, particularly in large municipalities such as Berlin, which should be taken into account when launching a sharing system. For example, the population density and car density in the real-world laboratories studied are higher compared to the districts in the center of Berlin (cf. AfS, 2021).

In Germany, the use of e-scooters is generally only permitted from the age of 14 (ADAC, 2023b). As with bicycles, the use of e-bikes is not subject to any age restrictions (ADAC, 2023c). According to the terms and conditions of the provider Bolt, the rental of both their e-scooters and e-bikes is only possible from the age of 18. Consulting Table 2, it can be seen that the age distribution in the real-world laboratories is not strikingly different. There is a potential for the use of the sharing offer of 82 - 85 % of the population in the real-world laboratories. A survey in Berlin and Dresden showed that around half of the e-scooter users surveyed were between 19 and 30 years old (cf. Ringhand et al., 2021).

Table 2: Age distribution in the districts of Lichtenrade, Zehlendorf (source: AfS, 2023) and Erkner (source: Landkreis Oder-Spree, 2021)

| **Real-world lab** | **Inhabitants** | **Age: from… to under… (share in %)** | | | | | | | | **Gender (share in %)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | under 6 | 6 - 15 | 15 - 18 | 18 - 27 | 27- 45 | 45 - 55 | 55 -65 | over 65 | female | male |
| Erkner | 11,935 | 5 | 8 | 2 | 6 | 20 | 16 | 12 | 31 | 53 | 47 |
| Lichtenrade | 52,419 | 6 | 9 | 3 | 9 | 20 | 12 | 15 | 26 | 56 | 44 |
| Zehlendorf | 54,722 | 4 | 8 | 3 | 9 | 18 | 12 | 16 | 29 | 54 | 46 |

### Public transport infrastructure

All real-world laboratories have a local bus network and at least one S-Bahn Berlin train station. Erkner is connected to Berlin by the S3 line from Erkner S-Bahn station. The frequency of the S3 is 20 minutes at peak times (see S-Bahn Berlin, 2022). There is also a connection to the regional train (RE1) at Erkner station. The Erkner bus station is located in the immediate vicinity of the train station and provides connections to the local bus network and surrounding municipalities. There are two S-Bahn stations each in the Lichtenrade and Zehlendorf real-world laboratories. In the Zehlendorf real-world laboratory, there is access to the S1 line at the S-Zehlendorf and S-Sundgauer Straße S-Bahn stations. At the S-Bahn stations S-Lichtenrade and S-Schichauweg, the S2 line runs in the Lichtenrade real-world lab (at the beginning of the real-world lab, the S2 line from Lichtenrade to Mahlow was closed due to construction work). The frequency of the S2 into the city alternates between six and 14 minutes. Outside of the city, this is ten minutes (see S-Bahn Berlin, 2022).

Since the information in the Public Transport Atlas covers the entire urban area of Berlin (see Table 1), the following section takes a closer look at the density of public transport in the real-world laboratories. The public transport priority network for Berlin is used for this purpose. The priority network represents routes on which public transport services are particularly dense and where there is also high demand. The average frequency on working days is less than ten minutes in both directions and the timetable provides for six trips per hour in both directions for at least twelve hours a day (see Berlin Senate Chancellery, 2023). Image 4 shows that this network is less dense in Zehlendorf and Lichtenrade compared to Berlin's city center. It can also be seen that the priority network in Lichtenrade does not cover the entire area, even on the main traffic axes. While this is the case in Zehlendorf, larger sections, primarily in the residential areas, are not covered.

This signifies that there are areas in both real-world labs that are insufficiently covered by public transport and therefore have the potential for alternative transport options such as shared vehicles. It can also be assumed that the population is more dependent on private cars. According to AfS (2021), the car density in these districts is in any case higher than in inner-city districts of Berlin.

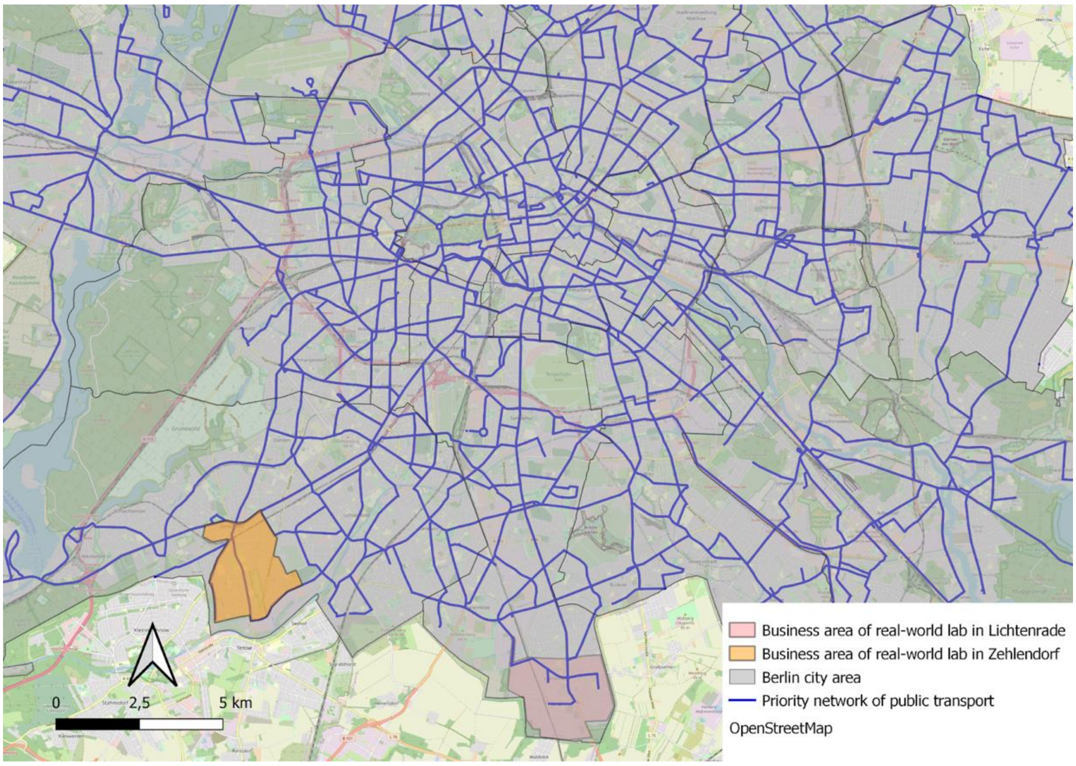

Image 4: Public transport priority network in Berlin (own presentation based on Geoportal Berlin, Fis-Broker, 2022)

## Area of comparison

As part of the project, usage data is collected for the various real-world labs and can therefore be compared. However, in order to be able to contextualize the usage in the city outskirts, the usage is compared with a comparative data set of an inner-city area of the provider (see Image 3). The selected comparison area comprises a section of Berlin's city center. This limitation was made, among other things, to exclude possible trips for tourist purposes in other parts of the city center in order to be able to establish better comparability with the real-world labs. For this reason, mainly residential areas were included in the comparison area. In addition, the selected section is intended to create better comparability with regard to the insularity of the real-world labs. The survey period covers the data from 17.05.2021 to 30.06.2022.

## 3.3. Design of the real-world labs: pricing and station systems

The design of the real-world labs is generally based on the question of how relevant stakeholders (municipality, providers, users, civilian population) perceive the sharing offer. It also considers how such an offer can be designed with as little conflict as possible and economically in accordance with these various particular interests. The design of the sharing offer in the real-world labs differs in three main points: the price for end customers, the parking model for the vehicles and the vehicle fleet.

**Pricing models**

Three fundamentally different pricing models were used to launch the sharing offer in the three real-world labs. The pricing models used are summarized in Table 3 and were implemented as follows at the start of the real-world laboratories:

- **Lichtenrade (regular price + incentive for returns near an S-Bahn train station)**:

  Prior to the introduction of the real-world labs in July 2022, the regular price at the provider Bolt in Berlin was €0.19 per minute without the unlocking fee that is standard in the sector. This price was adopted for the real-world labs in Lichtenrade in order to compare the results from the real-world labs with discounted rates with results from a real-world lab at standard market prices at the end of the study. In contrast, lower prices were applied in Zehlendorf and Erkner in order to compare demand at different prices. In contrast to a pricing structure that "punishes" a certain usage behavior (so-called push measure), which was applied in Zehlendorf, a pricing mechanism was chosen in Lichtenrade that was intended to "reward" a certain usage behavior (so-called pull measure). Specifically, incentives in the form of three free minutes were awarded for ending the journey at the S-Bahn stations in Lichtenrade, with the aim of financially rewarding a switch to the S-Bahn. The incentives were introduced at the same time as the service and were maintained throughout the entire operating period of the real-world laboratories. As the incentive was only granted for the completion of journeys at the S-Bahn train station, a comparison could be made with the proportion of journeys starting at the S-Bahn station for which there was no financial incentive. The influence of price incentives on intermodal use can therefore be investigated.

- **Erkner (low price)**:

  A comparatively low price of €0.14 per minute was set for Erkner - well below the industry average. The aim of the study was to investigate whether potential users in small towns that are comparatively far from the nearest regional center (in this case Berlin's city center) and have a high car density can be activated to an above-average extent using an attractive price.

- **Zehlendorf (progressive price)**:

  Studies show that in many cities where sharing systems are used, the majority of journeys are in the lower minute range (cf. e.g. Li et al., 2022). This observation was confirmed by the analysis of inner-city trips made by the provider Bolt in Berlin's core area (see Image 5). In Zehlendorf, as in Erkner, a price of €0.14 per minute was therefore introduced at the start of the journey. From the 13th minute, however, the price was doubled (€0.28 per minute). This progressive increase in the price was chosen in order to be able to test whether longer journeys to Berlin's city center, which would presumably otherwise have been made by public transport, could be prevented. Rather, this price approach was intended to examine whether short trips can be encouraged in order to promote a switch to public transport and in particular to the S-Bahn.

The approximate average usage time of Bolt trips in Berlin, 12 minutes, was chosen for the start of the progressive price increase. Within this time frame, it was also assumed that all locations within the real-world laboratory could be reached using a shared vehicle.

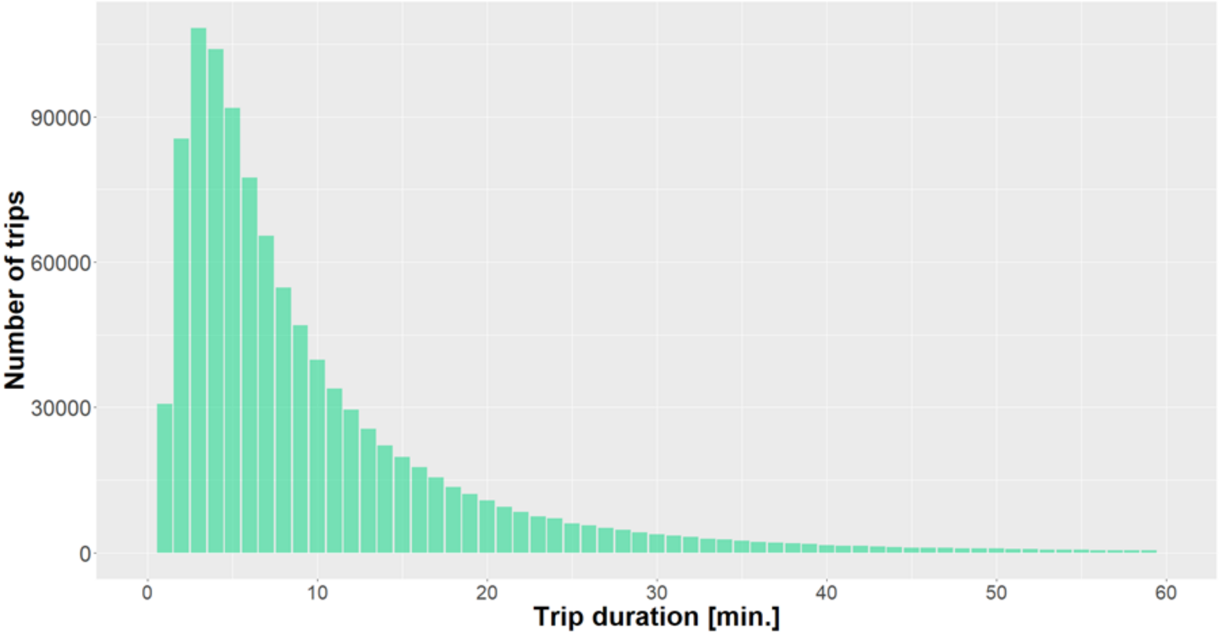

Image 5: Distribution of the duration of use of e-scooter trips in Berlin (inner city)

Due to the comparatively short distances between the two Berlin real-world laboratories and Bolt's inner-city operating area (see Image 3), there were a large number of unforeseen trips between these operating areas. Due to the method of assigning the selected prices to the individual vehicle, it did occur that vehicles in a real-world laboratory were available for rent at different prices. This made it possible to study the effect of different prices on demand and usage.

Table 3: Overview of the pricing models used (as at the project start)

| **Pricing model** | **Price** | **Reason and object of study** |
|---|---|---|
| Low price | 0.14 €/min. | Greater attractiveness and activation in remote areas with additional higher car density |
| Regular price | 0.19 €/min. | Analysis of utilization under normal market price |

| Pricing model | Price | Reason and object of study |
|---|---|---|
| Progressive price | 0.14 €/min. + doubling from the 13th minute | Avoidance of longer trips due to price increase |
| Incentive | 0.57 € when returned at specific stations | As an incentive to switch to local public transport, three free minutes were granted if the vehicle was returned close to the train stations. |

In the course of implementation, some of the prices in the real-world labs were increased in order to be able to examine the corresponding effects on usage behavior (see Table 4). The following price adjustments were made:

- **Erkner:**

  In Erkner, the launch price of €0.14 per minute was maintained from September 2022 to March 2023 with the aim of creating a longer familiarization phase for the new sharing service. In April and May 2023, the price was raised to the then regular price of € 0.26 per minute in order to examine the effects of a price increase on demand, as well as the profitability of operation under normal market conditions.

- **Lichtenrade:**

  In the course of the project, the price in Lichtenrade was successively raised to examine the corresponding effect on user behavior. The pricing structure in the regular business area in Berlin’s center served as a guide. Price increases in the center of Berlin were transferred in parallel to the real-world lab in Lichtenrade. Table 4 shows the dates and amounts of the price adjustments, which ranged from 8% to 16%. As a comparative value to this successive increase, a price increase of 86% was implemented in Erkner on 18.04.2023 (from €0.14/min to €0.26/min).

  The aim of this procedure was to analyze the price sensitivity of customers.

- **Zehlendorf:**

  Due to the fact already described that there were inbound and outbound trips between the real-world labs, the corresponding price increases can also be found to some extent in the other real-world laboratories, and in Zehlendorf in particular. Beyond this, no further price changes were made in Zehlendorf.

Table 4: Overview of price increases in the real-world laboratory in Lichtenrade

| Period | Applicable price |
|---|---|
| 18.07.22 – 26.10.22 | 0.19 €/min. |
| 27.10.22 – 09.03.23 | 0.22 €/min. |
| 10.03.23 – 03.05.23 | 0.24 €/min. |
| 04.05.23 – 31.05.23 | 0.26 €/min. |

### Station models

The potential advantages of different station systems have already been described: in theory, the free-floating system allows for greater flexibility for users when reaching their destination, whereas this flexibility is comparatively limited in a station-based system. On the other hand, station-based systems offer a promising solution for better regulation of parking or parking of sharing vehicles, which can lead to a significantly higher proportion of vehicles parked in accordance with the rules or not in an obstructive manner (cf. Gebhardt et al., 2021). Various options are now available for the design of station systems, which differ in terms of their effect on parking behavior, but also in terms of the associated costs for providers and municipalities and the acceptance of users. It is important to find a feasible and balanced solution for all stakeholders involved in this interplay of effects. For this reason, three different station models were used in the project in order to gain practical insights into the use of these systems on the outskirts of cities. The station models used in the project are described below and their selection is justified and explained:

- **Free-floating**: Vehicles can be parked throughout the entire operating area, with the exception of predefined no-parking zones (e.g. around green spaces or bodies of water). The free-floating system offers users the greatest possible flexibility and convenience and is therefore most comparable to the advantages of a private car. On the other hand, there is greater potential for conflict due to space conflicts on sidewalks. The use of a free-floating station system as part of the study allows the investigation of various aspects: for example, the effect on parking behavior. In addition, a system without a station link makes it possible to localize the start and destination of users very precisely. From this, hotspots can be derived and possible differences in usage behavior compared to station-based systems can be determined.
- **Virtual stations**: Virtual stations are fixed drop-off locations that are defined and displayed exclusively digitally, i.e. in the provider's app using so-called geofencing, without having an associated marking on the street or sidewalk (see Image 6). Due to existing inaccuracies in the GPS signal (cf. Caggiani et al., 2023), the station must be digitally defined slightly larger than the local area intended for parking the vehicles. Providers usually implement this digital buffer to avoid user frustration when parking or ending the journey. The station has not been designated locally, e.g. by means of markings on the ground. As part of the testing of this station model, it will be examined how reliable and effective this easy-to-implement "low-threshold" station model is. From the providers' point of view, this model is simple and quick to implement, as no structural or physical measures are required in road traffic (nor complicated permits) and the

digital implementation can done with comparatively little personnel effort. This means cost and time savings for both providers and local authorities and enables the service to be introduced quickly.

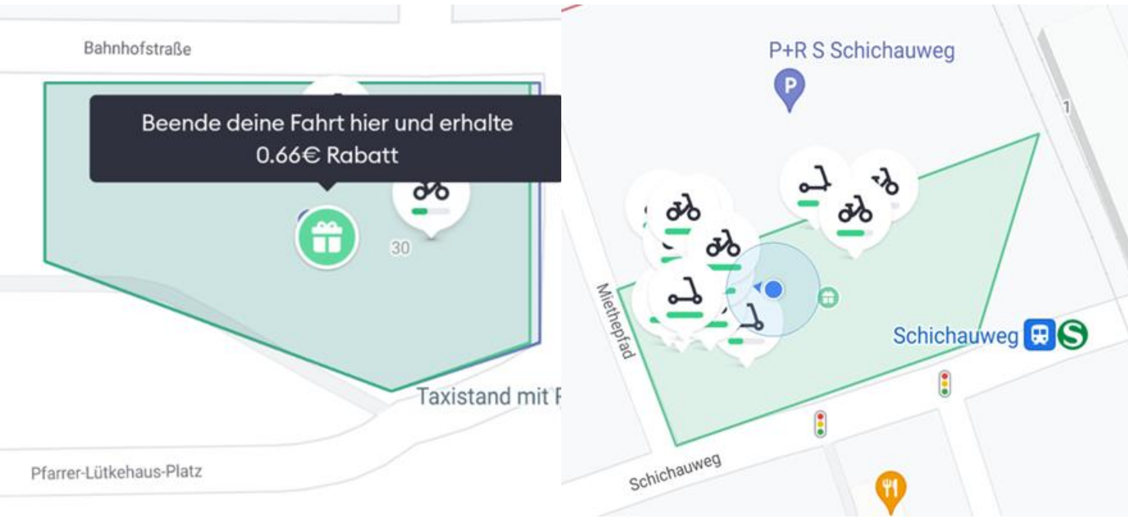

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Image 6: Illustration of the incentives in Lichtenrade in the Bolt app

- **Fixed local stations**: Parking is only permitted in locally marked stations (see Image 7). A virtual marker in the app serves as a link to the local station (see Image 7). Due to the aforementioned problems with the GPS signal, the local station in the provider's app is also defined as slightly larger than it actually is on site. The stations were simply marked with yellow colored stripes (see Image 7, Image 8). The aim here was to investigate the extent to which the color markings support sharing vehicles being parked properly. The station areas were set up both in the sidewalk area and on the road, making it possible to study whether one area is preferred and which solutions are recommended for the future regular operation of station systems. In early March 2023, additional pictograms were applied within the Bolt station area to clearly assign the yellow-marked station areas as exclusive areas for micro-mobility vehicles and e-bikes (see Image 8). The background to this measure was the repeated use of the station areas by other vehicles.

In Erkner and Lichtenrade, 33 stations were set up in each case. Due to the larger area of the operating area in Lichtenrade (see Table 1Table 1), the station density in Lichtenrade is therefore lower than in Erkner. This design allows the study of user satisfaction with regard to the degree of coverage of the operating area by stations.

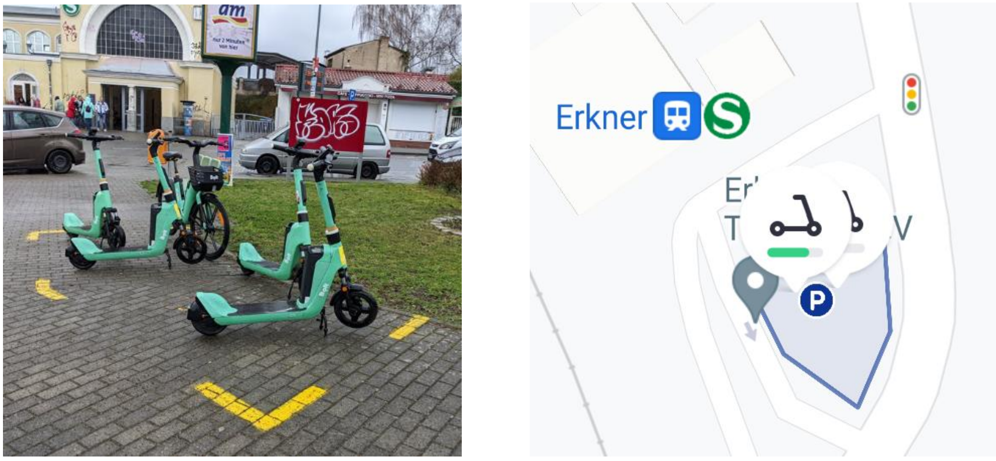

Image 7: Depiction of the station at S-Erkner in the app and local markings

Image 8: Station in Erkner without (left) and with (right) pictogram

### Vehicle fleet

At the start, fleets of 100 vehicles were used in all real-world laboratories, half of which were e-scooters and the other half e-bikes (see Table 5). The vehicles have different speed limits. The speed of the e-scooters is limited to 20 km/h and the electric drive assistance of the e-bikes is limited to 25 km/h. Both vehicle types have different parking space requirements, with an e-scooter taking up slightly less space than an e-bike.

The use of e-scooters is referred to as passive mobility, while e-bike use represents active mobility. By offering both forms of mobility in the real-world laboratories, it was possible to study which type of vehicle is preferred by users in suburban locations. The underlying reasons for a possible preference will be determined in the course of the survey. This will make it possible to determine how the fleet composition in suburban operating areas should be selected in future. In order to be able to observe which vehicle type is preferred under the same conditions, both in terms of price and supply density, no price difference was assumed for the two vehicle types.

During the test period, vehicles were repeatedly driven from the Berlin city center business area to the Lichtenrade and Zehlendorf real-world laboratories. As a result, it was not possible to guarantee an even distribution of vehicles in these two real-world laboratories. There was no such mixing of vehicles in Erkner, which is why this real-world laboratory is applicable and reliable to analyze the vehicle use.

Table 5: Summary of the pricing and station models and vehicle fleets in the respective real-world laboratories

| Real-life lab | Pricing model | Station model | Vehicle fleet |
|---|---|---|---|
| Erkner | Low price (0.14 €/min) | Station-bound with local marking | 50 e-bikes<br>50 e-scooters |
| Lichtenrade | Regular price (0.19 €/min) | Station-bound without local marking | 50 e-bikes<br>50 e-scooters |
| Zehlendorf | progressive pricing (0.14 €/min + doubling from the 13th min.) | Free-floating | 50 e-bikes<br>50 e-scooters |

## 3.4. Survey of parking violations

The main criticism of sharing services offering e-scooters and e-bikes is mainly directed at incorrectly parked sharing vehicles that affect other road users. For this reason, parking violations such as parking the vehicle outside the designated markings were regularly studied as part of the project.

The parking violations were assessed on the basis of the 2.30 m of free remaining pavement width required by the Berlin Streets Act when parking micro-mobility vehicles. The 2.30 m free remaining pavement width is a requirement for the sharing providers of micro-mobility vehicles from the ancillary provisions for special use of the City of Berlin. The classification of parking violations in the real-world laboratories is based on the remaining width of the remaining walkway and is intended to enable a qualitative classification of the functioning of the station systems on the outskirts of the city. In addition, third-party use of the station areas by vehicles and compliance with the specified station areas were determined. For the virtual stations, the virtual area in the app was used as the basis for this. Accordingly, only a general assessment of the respective vulnerabilities of the station models in the traffic infrastructure on the outskirts of the city is to be made in order to be able to derive targeted measures and make recommendations with the help of the resulting findings.

A total of seven on-site inspections were carried out, two each in Lichtenrade and Zehlendorf and three in Erkner. An additional survey in Erkner was necessary because pictograms were added within the sharing stations during the course of the project. The aim of the additional survey was to evaluate the influence of these markings on the clear identifiability of the area as a sharing parking space. As an indicator for this, the number of vehicles parked within the station as well as any third-party use by vehicles before and after the pictograms were compared.

## 3.5.Quantitative analysis and GIS analyses

The data sets of the provider Bolt are available for quantitative evaluations and geographical representations. This data was provided for the studied real-world laboratories, including the attributes trip length, trip distance, start and end point of the trips, price and an anonymized assignment of the users. From these data sets, findings on usage behavior on the city outskirts can be extracted using descriptive statistical analyses and geographical information systems (GIS). A data set with equivalent attributes is also available for the inner-city comparison area of Berlin.

## 3.6.Survey

In order to be able to carry out further analyses of usage behavior, app-based surveys of users were conducted in the real-world laboratories. In Erkner, the survey was also continued from June 2023 via the Erkner city website, as the sharing service there was initially discontinued after the end of the pilot project, unlike in Lichtenrade and Zehlendorf. Table 6 shows an overview of the surveys for each real-world lab.

The survey was presented to existing users in the real-world labs via push notifications in the Bolt app as soon as users opened the app. This ensured that only active users of the sharing service were surveyed. Depending on the real-world lab, the questionnaires contain four to five thematic sections:

- general use,
- use in conjunction with other means of transportation (public transport and cars),
- vehicle review,
- station review and
- socio demographics.

Table 6: Overview of the conducted surveys

| **Real-life lab** | **Survey type** | **Survey period** | **Number of complete participations** |
|---|---|---|---|
| Erkner | In-app survey + website of the city of Erkner | 19.05.2023 – 30.06.2023 | N = 30 |
| Lichtenrade | In-app survey | 19.05.2023 – 30.06.2023 | N = 94 |
| Zehlendorf | In-app survey | 19.05.2023 – 30.06.2023 | N = 80 |

Concerning general vehicle use, questions were asked about the frequency, the purpose of the trip and the planned use of the sharing service. Further questions included whether the sharing service was used in combination with the S-Bahn (intermodal transport), whether and what reasons there were for using it as an alternative to the bus and whether the sharing service was possibly a substitute for driving a private car. The survey also inquired which type of vehicle was preferred and why.

In the real-world laboratories where the vehicles had to be returned at the stations (Erkner and Lichtenrade), participants were asked to evaluate the location of the station, the quality and the functionality of the two station models.

The surveys were conducted from 19.05.2023 to 30.06.2023. In Zehlendorf, 158 participants started, but only 80 persons completed the survey. In Lichtenrade, these figures were 179 to 94 and in Erkner 57 to 30. Of these, four participants in Erkner had to be removed from the data set due to insufficient data. A total of 200 completed surveys were therefore included in the analysis.

Table 7 shows the age, gender and income distribution among the respondents.[1] For Lichtenrade and Zehlendorf, it is evident that the age distribution is similar to previous surveys on the use of e-scooters (see Ringhand et al., 2021). In both operating areas, half of the respondents were between 18 and 27 years old. In Erkner, however, usage tends to be among slightly older people based on the survey. The largest group is between 27- and 45-year-olds. In all three real-world laboratories, the proportion of male users is at least two thirds. This is congruent with the empirical work on target groups for e-scooters conducted by Anke et al. (2022).

Previous findings in the literature indicate that e-scooter users have a higher income (Gebhardt et al., 2021). However, a different distribution is emerging in Lichtenrade and Zehlendorf in particular. The largest group of users (27% and 29%) reported a monthly net income of less than €900. If the predominantly young clientele (18 - 27 years) is also considered, this income group could be trainees or students, something that was not surveyed within the scope of this project. This should be included in future studies in any case.

Table 7: Socio-demographic data of the survey participants

| Real-world labs<br>Sample size | Erkner<br>n = 26, share in [%] | Lichtenrade<br>n = 94, share in [%] | Zehlendorf<br>n = 80, share in [%] |
|---|---|---|---|
| **Age group (from … to under …)** | | | |
| 15-18 | / | 2 | 3 |
| 18-27 | 19 | 49 | 49 |
| 27-45 | 50 | 36 | 29 |
| 45-55 | 27 | 7 | 12 |
| 55-65 | 4 | 1 | 4 |
| over 65 | / | 4 | 1 |
| **Gender** | | | |
| female | 19 | 30 | 27 |
| male | 77 | 67 | 71 |
| other | 4 | 3 | 3 |

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[1] The classification of the age groups is based on the classification of the Berlin-Brandenburg Statistical Office in order to be able to draw a comparison with the respective total population. Also for reasons of comparability, net income was categorized based on the Destatis classification (Destatis, 2023).

| Real-world labs<br>Sample size | Erkner<br>n = 26, share in [%] | Lichtenrade<br>n = 94, share in [%] | Zehlendorf<br>n = 80, share in [%] |
|---|---|---|---|
| **Net income [€]** | | | |
| below 900 | 4 | 29 | 27 |
| 900 – 1,300 | 12 | 14 | 15 |
| 1,301 – 1,500 | 8 | 12 | 5 |
| 1,501 – 2,000 | 8 | 11 | 14 |
| 2,001 – 2,600 | 28 | 14 | 15 |
| 2,601 – 3,600 | 16 | 5 | 7 |
| 3,601 – 5,000 | 12 | 7 | 5 |
| above 5,000 | 12 | 8 | 12 |

In addition to the user surveys in the real-world laboratories, the residents of Erkner and the surrounding area were also surveyed. The evaluation of this survey is not discussed further in this study. The results will be presented in a further publication.

## 3.7.Expert interviews

In addition to studying user behavior, seven expert interviews were also conducted as part of the real-world lab. The aim of these interviews was to find out how other stakeholders perceive and assess the real-world laboratories and Bolt's sharing system in terms of a sustainable supplement to public transport, as well as to identify different stakeholder needs concerning the holistic integration of a new sharing service.

In the course of the project, it became apparent that the provision of the sharing system takes place in a complex construct of opposing interests and usage claims and conflicts. Therefore, interviews were conducted with stakeholders from political and administrative bodies, with employees of the provider and others at the strategic municipal level. Seven guided interviews were conducted between 12.07.23 and 18.08.23. The interviews lasted between 40 and 60 minutes.

The interviews were recorded, then transcribed and the transcripts were subjected to a qualitative content analysis according to Mayring & Fenzl (2019) in order to extract and generalize the most important information. For this purpose, the most important statements were paraphrased, generalized by coding and then redundancies were removed. In a final step, the remaining generalizations were bundled and then reduced by theme.

The most important findings from the interviews conducted with the experts are also integrated into the thematically structured evaluations of the results in Chapter 4. Based on these results, recommendations for action for the future operation of sharing systems are derived.

# 4. Research results

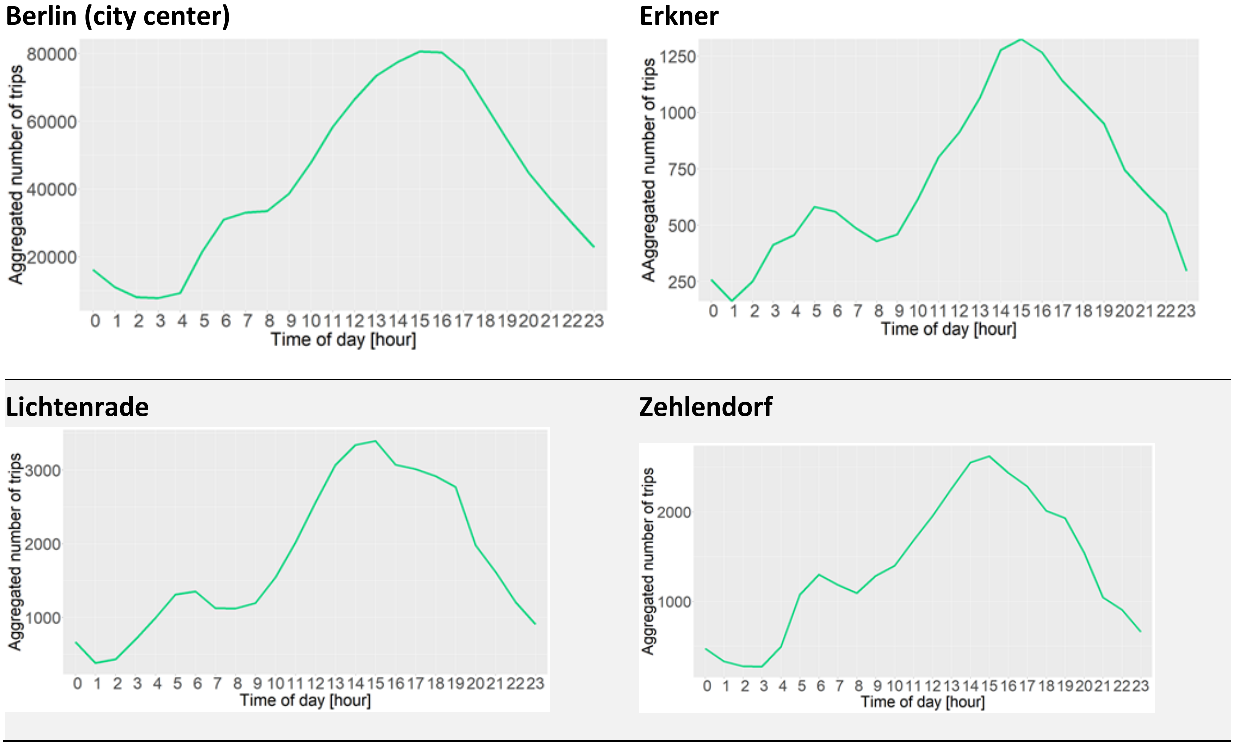
The project's results are summarized here, starting with the analyses of general usage behavior, which serve as the basis for further analyses in this chapter.

## 4.1. General usage behavior

As part of the analysis of general usage behavior, the parameters "frequency of use" and "density of use" as well as "usage planning" and "purposes of use" are considered.

### 4.1.1. Density and frequency of use

The density of use over time can be depicted in so-called daily hydrographs. The daily hydrographs in the real-life laboratories are very similar to the inner-city daily hydrographs (comparison area) and differ mainly in the morning hours (cf. Image 9). Here, usage between 1 a.m. and 6 a.m. is higher in the real-life laboratories than in the city center. An obvious assumption for this accumulation of trips in the morning is the thinned public transport timetable on the city outskirts in this period. As a consequence, users were asked in the survey whether they use the sharing service in the morning or late evening hours for this reason (see Chapter 5.2).



**Berlin (city center)**

**Erkner**

**Lichtenrade**

**Zehlendorf**

Image 9: Daily course of use in all real-life laboratories and in the comparison area in Berlin

***The frequency of use of the sharing offer is very similar in the real-world laboratories on the outskirts of the city compared to Berlin's city center***

Many users only used the service once during the survey period, with only a few using the service very frequently. The proportion of "trial users" who only made one trip during the survey period ranges between 32 and 48%. However, this group only made up 3-6% of trips(depending on the real-world laboratory; see Table 8). On the other hand, there are users who use the sharing service more than twice a week on average. Here, the proportion of trips on the outskirts of the city and trips in Berlin's city center, Lichtenrade and Zehlendorf is almost identical: 1-2% of users account for 29-30% of trips. In Erkner, these proportions were even higher: 3% of users made 40% of all trips. It should also be noted that the average number of trips per user is highest in Erkner at 12.3. In Lichtenrade, this figure is 9.6 and in Zehlendorf only 8.0. For the inner-city comparison area in Berlin, this figure is 10.2.

Table 8: Frequency of use in the real-life laboratories compared to Berlin's city center

| **Frequency of use** | | **Berlin** | **Erkner** | **Lichtenrade** | **Zehlendorf** |
|---|---|---|---|---|---|
| | | Share in % | | | |
| **One-time** | Users | 38 | 32 | 42 | 48 |
| | Trips | 4 | 3 | 4 | 6 |
| **Less than once per month** | Users | 48 | 41 | 40 | 38 |
| | Trips | 20 | 12 | 17 | 19 |
| **Once per month** | Users | 1 | 2 | 1 | 1 |
| | Trips | 1 | 1 | 1 | 1 |
| **Multiple times per month** | Users | 10 | 17 | 12 | 10 |
| | Trips | 28 | 26 | 27 | 27 |
| **Up to twice per week** | Users | 2 | 4 | 3 | 2 |
| | Trips | 18 | 18 | 22 | 18 |
| **Twice or more per week** | Users | 1 | 3 | 2 | 1 |
| | Trips | 29 | 40 | 30 | 30 |

### *Wide range of frequency of use observed*

The values shown for the frequency of use in the three areas refer to the entire study period (see Table 8). When looking at the average value, it is possible that a user may have used the service rarely at the beginning, but more regularly over the course of the project or vice versa. In order to gain a more detailed understanding of the frequency of use several months after the start of the service, this aspect was also queried as part of the survey. The results of the survey indicate regular use of the service by a large proportion of users (see Image 10). According to their own statements, 35-41% use the service several times a week. A comparison of the free-floating and station-based systems in Lichtenrade and Zehlendorf reveals that both concepts have comparable usage densities. In terms of individual users and usage density, Lichtenrade (virtual station-based parking system) is slightly higher. The proportion of one-time use is highest in Zehlendorf (free-floating system) at around 48% (see Table 9).

Table 9: Density of use in the real-world laboratories compared to Berlin's city center

| Frequency of use | Berlin | Erkner | Lichtenrade | Zehlendorf |
|---|---|---|---|---|
| **Number of trips** | 1,022,920 | 16,691 | 42,638 | 33,062 |
| **Area [m²]** | 42.4 | 3.9 | 6.1 | 5.9 |
| **Number of examined days** | 410 | 255 | 318 | 318 |
| **Usage per day** | 2,494.9 | 65.5 | 134.1 | 104.0 |
| **Density of use**<br>**[uses per day /km²]** | 58.84 | 16.78 | 21.98 | 17.62 |

***The density of use on the outskirts of Berlin is significantly lower than in the city center.***

The frequency of use in relation to the area (density of use) is similar in all real-world labs, but around three times lower than in Berlin's city center (see Table 9).

The usage density can also be determined by the daily utilization of the vehicles. However, this parameter is not suitable in this project in some cases, as the original fleet in Lichtenrade and Zehlendorf was quickly mixed with vehicles from the rest of the operating area. For Erkner, however, this parameter can be significantly determined, as the vehicles remained almost exclusively in the operating area over the entire testing period. Vehicles from other city areas were only added to a very small extent (see Table 10). At 0.7 trips per day, the average utilization per vehicle in Erkner is low. To compare: According to statistics from 2019, Potsdam had the lowest utilization of all cities surveyed with 1.5 trips per day (Statista, 2023). In Hamburg, on the other hand, two sharing providers achieved an average of 1.7 to 2.2 daily trips per vehicle between May and October 2020 (Reintjes, 2020). In this context, it becomes clear how low the figure for Erkner is.

The number of trips per day in the operating area can be used as a valid comparative value for all real-world laboratories. This shows that more than twice as many trips per day are made in the station-based system in Lichtenrade than in Erkner. The value for daily use in Zehlendorf is roughly in the middle (Table 9).

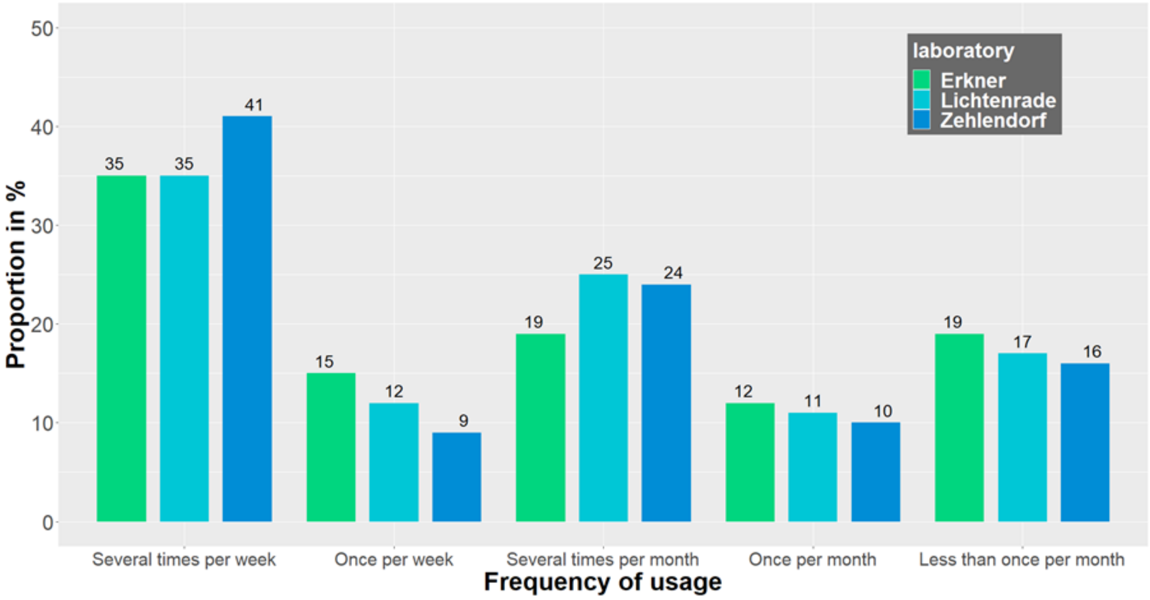


Image 10: Breakdown of responses on frequency of use, n = 199

The lower absolute use in Erkner can be attributed to the low population density, as Erkner has the highest proportion of trips in relation to the population. Around 1.4 trips per resident were made there, whereas this figure is 0.8 for Lichtenrade and 0.6 for Zehlendorf. Due to the higher population density in Berlin's outer districts, higher vehicle utilization rates can be achieved.[2] Accordingly, the highest number of trips in absolute terms and per area can be recorded in the operating area with the highest population density (Lichtenrade). Vice versa, the fewest trips based on these parameters were made in the operating area with the lowest population density.

Table 10: Proportion of incoming and outgoing trips in the real-world laboratories

| **Real-world laboratories** | **Share of trips within** | **entering** | **leaving** |
|---|---|---|---|
| **Erkner** | 96 % | 2.5 % | 1.5 % |
| **Lichtenrade** | 87 % | 7 % | 6 % |
| **Zehlendorf** | 78 % | 11 % | 11 % |

---

[2] The operating areas do not cover the entire district or municipality: in Erkner, however, the majority of local residences are included in comparison to the other real-world labs. This means that the actual number of residents to be taken into account is actually lower for Lichtenrade and Zehlendorf. On the other hand, the catchment area for other users is larger in Lichtenrade and Zehlendorf than in Erkner due to the surrounding residential areas. Even with a reduction in the number of residents included, the value in Lichtenrade and Zehlendorf would at least be in a similar range to Erkner, which shows that the population density in the areas investigated results in higher absolute usage and can therefore be assessed as the most attractive for the provider from a purely private-sector perspective.

### 4.1.2. Utilization planning and purposes

***In areas with reduced public transport services and unreliable public transport connections: Sharing services are used as a reliable and flexible transportation option***

To discover the extent that the use of the sharing offer is already planned into daily mobility or is an integral part of daily mobility routines, this was also addressed in the survey. The majority of respondents stated that they borrow vehicles spontaneously or use a mixture of spontaneous and planned use (see Image 11). Across all survey areas, every sixth to eighth user plans on using the sharing service in advance for the respective routes or partial routes to be covered as a means of transportation. A connection can be made here to the reasons given for using the service as an alternative to the bus. In this context, a spontaneous use occurs as soon as a bus is delayed or even canceled (see chapter 4.2). This means that users make use of the sharing service as a reliable and flexible transport option in areas with fewer public transport services and unreliable public transport connections.

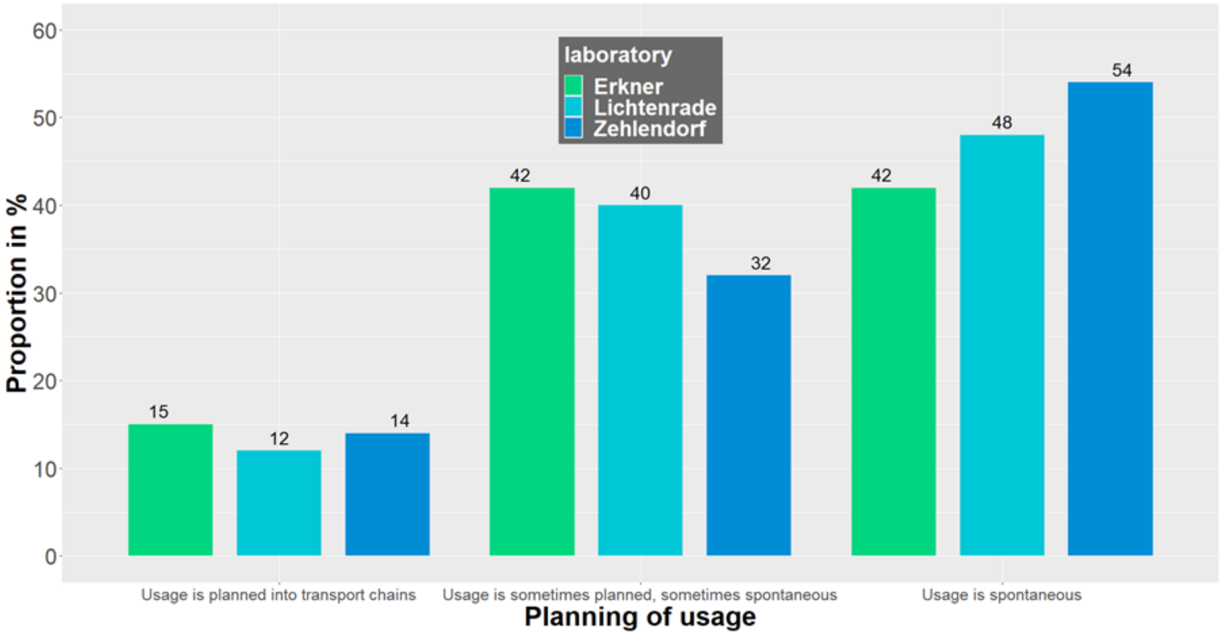


Image 11: Breakdown of spontaneous and planned use (n = 198)

***Regardless of whether it's a small town (Erkner) or a Berlin suburb (Lichtenrade, Zehlendorf): the distribution of travel purposes is almost the same***

In addition to the previously analyzed frequency of use, it is also essential to gain an understanding of the users' travel purposes in order to derive further criteria for the future design of the sharing offer on the outskirts of the city. The breakdown of responses are shown in Image 12.

The most frequent use is commuting to work or on the way home and in connection with leisure travel. This is also consistent with the findings of previous surveys on utilization in predominantly inner-city business areas (Difu, 2022). It is striking that the breakdown of trip purposes is very similar in the three real-world laboratories. Only the proportion of use for commuting to work is slightly lower in Lichtenrade, which is offset by the higher proportion of use for errands. All in all, it can be stated that the high proportions of trips to work and home are most likely related to increased use in the morning hours (see Image 9) and intermodal use with the S-Bahn train (see Chapter 4.2).

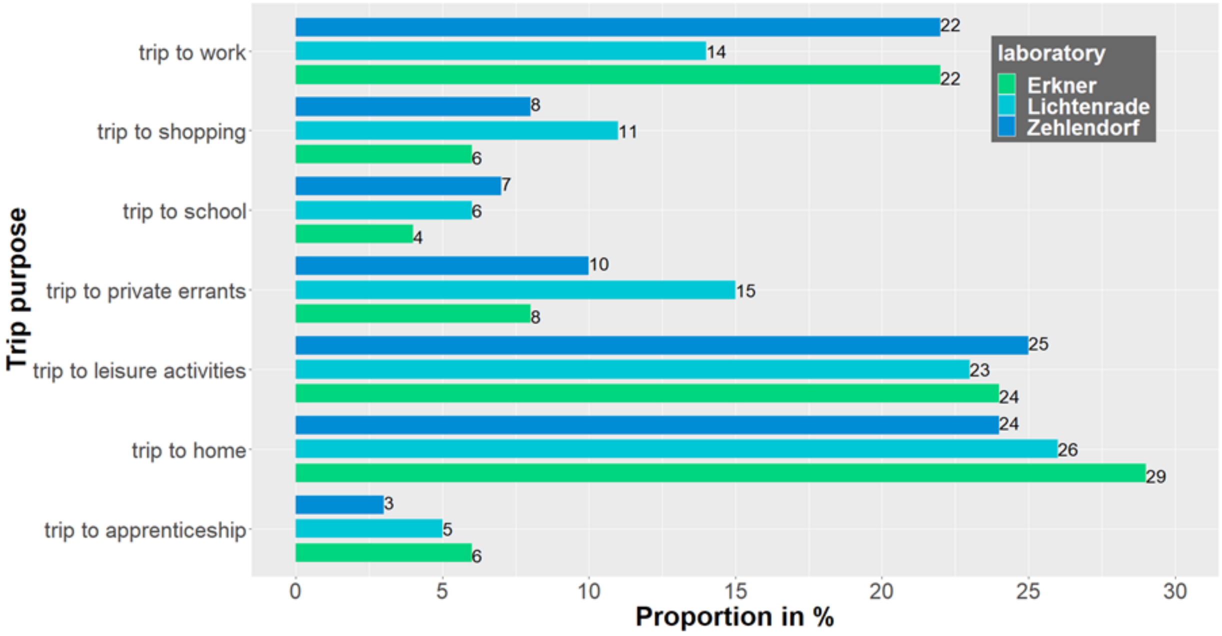


Image 12: Purposes for using the sharing offer in the three real-world laboratories

There were only minimal differences in the average distance traveled in all of the real-world laboratories, but these are negligible. The average use in the real-world labs was 1.6 - 1.9 km per trip. The value for the comparison area in Berlin is 1.8 km.

### 4.1.3. Conclusions

Even on the city outskirts, the share of users who had only tried the service once was predominant. Nevertheless, a proportion of users can be identified for all real-world laboratories who, although they represent a very small proportion of all users, make a disproportionately high number of trips. As a result, the future task for providers is to provide appropriate incentives in the service for both user groups (“trial users” and “frequent users”).

However, the demand for sharing services due to limited public mobility options does not necessarily lead to an above-average usage density. The density of use in the real-world laboratories studied is very heterogeneous. This can most likely be attributed to the different population densities. Contrary to the formulated Thesis 3 (see Chapter 2.3), sharing services are not used to the same or greater extent in the outer districts as in the city center. This poses a challenge for future operations. Where a sharing service can best reduce dependency on cars and supplement a patchy public transport service, i.e. often in areas with a lower population density, the density of use is lower as a consequence and makes the respective operating area uneconomical for the provider. In this constellation, it is therefore important for both local authorities and providers to work together to develop solutions and concepts for operations that cover costs.

## 4.2.Feeder to the public transport system and alternative means of transport

This chapter analyzes the possible role of sharing services as a supplement and feeder to public transport on the city outskirts. Furthermore, the potential of sharing services to replace car journeys on the outskirts of the city is examined.

### 4.2.1. Feeder function to the public transport system

***24 - 35 % depending on the real-world laboratory, use the shared vehicles several times a week to reach the S-Bahn train***

To assess the general extent to which the sharing vehicles are used as part of intermodal trip chains, the share of journeys made at the S-Bahn stations in the real-world laboratories can be used as a reference value. In all real-world laboratories, the S-Bahn stations were the most frequented of all possible destinations. Every fourth to fifth journey in station-based systems ends at an S-Bahn station, which is the highest concentration of all destinations in the corresponding operating areas (see Table 11).[3]

Table 11: Share of trips in the real-world lab that started or ended at the S-Bahn station

| **Real-world lab** | **Erkner** | **Lichtenrade** | | | **Zehlendorf** | | |
|---|---|---|---|---|---|---|---|
| **S-Bahn station** | **S-Erkner (+town hall)** | **S-Lichtenrade** | **S-Schichauweg** | **Total** | **S-Zehlendorf** | **S-Sundgauer Straße** | **Total** |
| **Share of trips started [%]** | 21 | 13 | 11 | 23 | 8 | 6 | 13 |
| **Share of trips ended [%]** | 19 | 12 | 11 | 23 | 7 | 5 | 12 |

The high frequency of use of the S-Bahn train stations does not necessarily indicate a transfer to the S-Bahn trains and thus a feeder function of the sharing service. However, the three surveys showed that a significant proportion of respondents (between 24 and 35% depending on the real-world laboratory) use the sharing service several times a week to transfer to the S-Bahn train or continue their journey

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[3] In the real-world laboratory in which a free-floating system was used to park the vehicles (Zehlendorf), the concentration of trips in the vicinity of the S-Bahn stations is similarly dense and the vicinity of the Zehlendorf S-Bahn station also corresponds to the most frequent destination of all trips (see Image 14). The lower proportions in Table 11 can be explained by the fact that, in contrast to the real-world laboratories with station-based parking, the vehicles could be parked over a larger area in the vicinity of the stations, but a limitation had to be made for a comparable quantification. Therefore, the coordinates of the stop entrances of the Berlin-Brandenburg transport association were used as a uniform boundary for recording the trips ending in the station area (VBB, 2021). The stations in the other real-world laboratories were within these coordinates, which meant that all vehicles at the stations could be recorded, but not all vehicles were recorded in Zehlendorf, especially at S-Zehlendorf.

from there in a shared vehicle (see Image 13). In addition, between 20 and 35% of users use the service weekly or at least several times a month as a feeder to public transport.

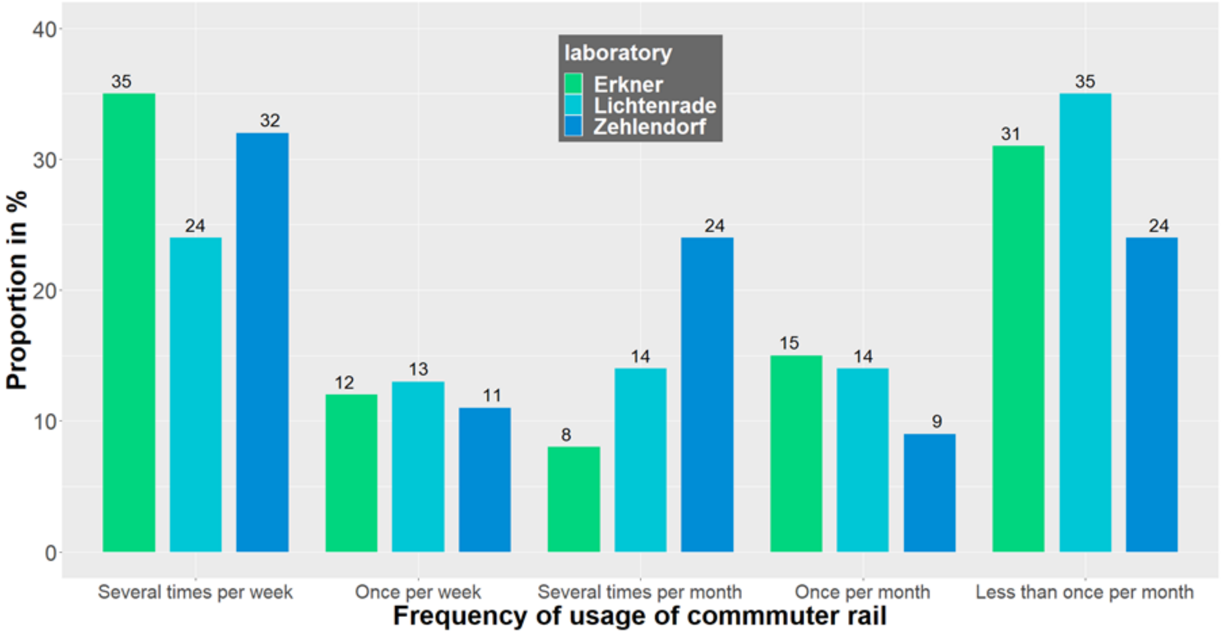

Image 13: Breakdown of the frequency of use of the S-Bahn train in the survey (n = 198)

To gain an even deeper insight into intermodal use, Image 14 shows the distribution of destinations per real-world laboratory in the form of a heat map. The dense red dots in Erkner and Lichtenrade correspond to the stations set up locally. In both the free-floating and the station-based systems, the largest agglomeration (hotspot) is in the area of the S-Bahn stations. There is a further strong concentration in Zehlendorf north of the Zehlendorf S-Bahn station along Teltower Damm, the town center and the district's supply center (town hall, optician, pharmacy, etc.). There is also a greater concentration in the area of the Zehlendorf Eiche bus stop. Twelve bus lines connect here (BVG, 2023a). In Zehlendorf, there is also a greater concentration along the boundaries of the operating area. This suggests that there is demand for a further expansion of the operating area examined. The municipality of Teltow (Brandenburg) is located at the southern end of the operating area in Zehlendorf. An expansion of the operation would thus only be possible after further coordination between the provider and the municipality.

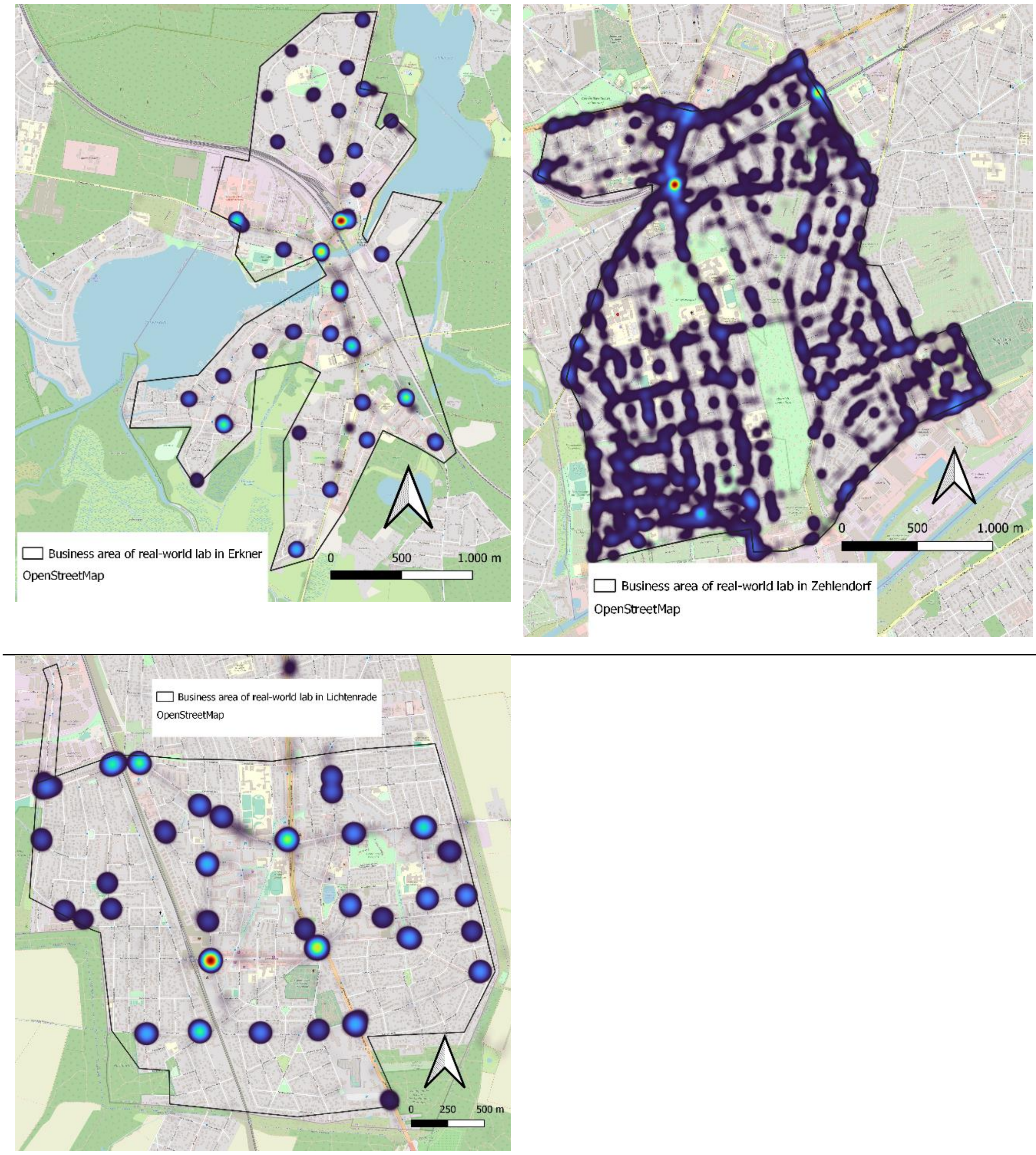

Image 14: Heat maps for trip ends in the real-world labs

In Lichtenrade, in addition to the S-Bahn train stations, further hotspots are emerging at the intersections Goltzstr./Lichtenrader Damm (three bus lines) and Lichtenrader Damm/Barnetstr. (five bus lines) (BVG, 2023b, BVG, 2023c). These intersections are junctions of the local bus network and are located on the connecting roads to the two S-Bahn train stations in the real-world lab in Lichtenrade. A further hotspot can be identified in Erkner southwest of the station at Friedensplatz, which acts as a connection between the northern and southern parts of the city (roundabout).

Overall, the heat maps show a large-scale distribution in the residential areas on the city outskirts. These account for the majority of trips. It can be deduced from this that there are more routes between important public transport stops and the residential areas (see Appendix 3: Originating traffic at S-Bahn stations in real-world labs).

***Commuters use the shared vehicles in outskirts as an alternative to the bus***

The survey results make it evident that the sharing vehicles were mainly used as an alternative to buses (around 70-90% depending on the real-world laboratory) (see Image 15). The most frequently cited reason for "use as an alternative" is that the sharing service is generally more available than local buses (26-34%). Sharing vehicles are used as an alternative, particularly in the evening when bus services are no longer available (20-30%). The sharing service is also used in the morning hours as a substitute for bus routes that are not yet serviced (10-1 %). In addition, 16-22% of users rate the trip with a shared vehicle as more comfortable than the bus.

Other reasons cited for the alternative use of shared micro mobility to bus services are:

- delayed bus,
- disrupted bus,
- waiting too long for the bus,
- no bus service on the desired route,
- Faster than the bus due to the option of avoiding traffic jams, e.g. by using the bicycle infrastructure.

These use cases also show the advantages that a sharing service with high availability can have for users.

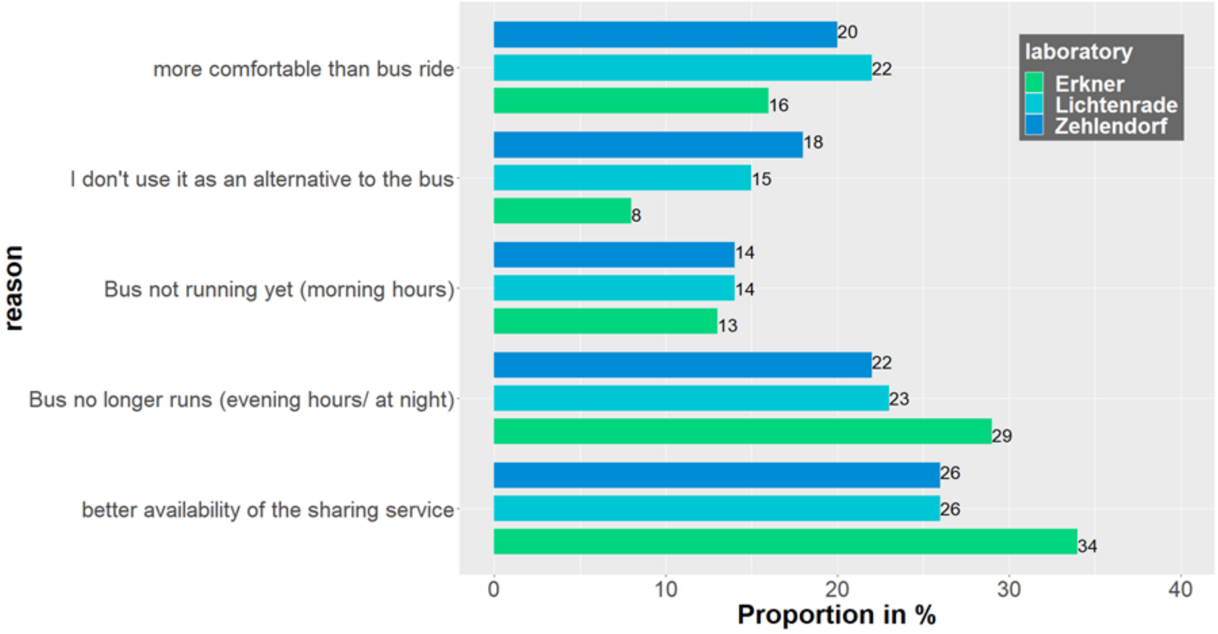

Image 15: Reasons for using the sharing service as an alternative to the bus (n = 200)

Sharing services are of particular interest when it comes to infrequent or unreliable services, as they can compensate for existing deficits in the offer of local public transport. Although the sharing service substitutes public transport in part, especially buses, it serves users as a mobility service with greater availability. This provides greater flexibility in everyday mobility.

### 4.2.2. Substitution of car trips

**Sharing services offer great potential for reducing trips with cars on the city outskirts**

In addition to supplementing public transport, the option of a possible substitution of car trips with shared vehicles is also relevant. In all real-world laboratories, 75% of all trips amount to less than 2.3 km or less (see Appendix 2: Boxplots for trip duration per price). Theoretically, sharing services would therefore have the potential to replace the 30 million car journeys per day in Germany that are less than 2 km (Gebhardt et al., 2021). In view of the average trip length of 1.6 - 1.9 km per day in the business areas surveyed (see Chapter 5.1.2.), this constellation indicates a high potential for the use of shared micro mobility for short trips that are currently still made by car. To this end, users were asked whether and how often they use the sharing service as an alternative to the car (see Image 16).

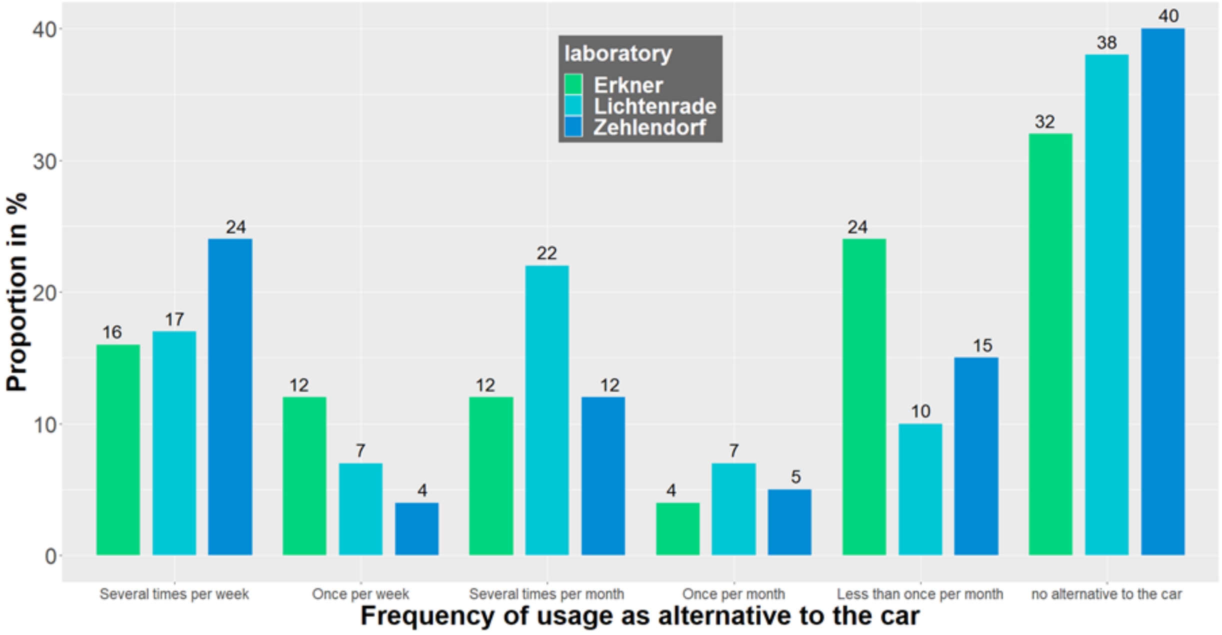

Image 16: Response breakdown on the frequency of use of the sharing service as an alternative to the car (n = 197)

For all real-world laboratories, the surveys reveal that users utilize the sharing as an alternative means of transportation to the car. Depending on the real-world laboratory, around 60-70% of respondents stated that they use the sharing service as an alternative to the car, although the frequency of this alternative use varies widely. Roughly a quarter of respondents stated that they replace their car with a sharing service at least once a week. Overall, a rough average of 20% even make use of these instead of their car several times a week. 30-40 % of surveyed individuals do not even consider the service as a true alternative to their cars.

### 4.2.3. Conclusions

In the context of the study of how sharing services function as a link to local public transport, it can be determined that they are used intermodally to a high degree. This is predominantly in conjunction with the S-Bahn train service. The frequency of use of the sharing service as part of an intermodal route chain with the S-Bahn is largely distributed heterogeneously in all real-world laboratories. About one in two persons report regular use. Furthermore, it can be shown that the sharing service is used in all real-world laboratories as a supplement to the patchy bus network. These functions should be further expanded and consolidated in the future through additional measures, such as integration into the public transport service.

In addition to physical factors that make it possible to use the sharing offer as a link to public transport, such as various station and pricing models, the digital presence and planning of the offer also play a significant role when using rental vehicles as a means of transport in intermodal route chains in combination with public transport. In Berlin, the Jelbi app can be used to search for a combination of several means of transport for the planned route in a compact and simplified manner (cf. BMWK, 2023). Accordingly, the use of the Jelbi app can promote an intermodal link between sharing services and public transport (cf. Bartnik, 2021).

Areas close to bus stops should be selected for the station areas. The most important reason for using sharing vehicles instead of the bus is the higher availability across all real-world laboratories, especially during off-peak hours and at night. From this, one need for action for providers can be deduced that a high availability of vehicles is primarily important at parking areas in the immediate vicinity of bus stops, without the transfer traffic at the bus stop being impaired by parked vehicles.

Sharing services on the city outskirts have the potential to replace car journeys in the outer areas that come with a high level of car dependency, particularly over short distances. They are already doing this to a certain degree. However, the extent to which car journeys are replaced by sharing services in the outskirts varies greatly and also depends on other external factors. The specific influence on local traffic patterns should be included in further studies.

Based on the findings described above, Thesis 2 (see Chapter 2.3) can be assessed as correct. This states that sharing services can supplement and make public transport on the outskirts of the city more attractive. The high proportion of trips associated with the use of the S-Bahn train and the complementary function to local bus services underlines this thesis.

## 4.3. Vehicle-related usage preferences

With regard to the choice between available types of vehicles (e-bikes and e-scooters), a clear tendency towards e-scooters can be determined based on the evaluation of the usage data and the surveys. The results for both vehicle types are explained in the following.

### 4.3.1. E-scooters

All real-world laboratories began with a fleet comprising one half e-scooters and the other half e-bikes (pedelecs). It is clearly evident in all real-world laboratories that the e-scooter vehicle type is preferred over e-bikes. In Lichtenrade, this vehicle type was used by 86% and in Zehlendorf by 83%. Due to the high number of incoming and outgoing journeys in these two real-world laboratories and the resulting partially distorted usage statistics, the real-world laboratory in Erkner offers the most meaningful result thanks to its insular location and the even distribution of its fleet.

The real-world laboratory in Erkner has the relatively highest use of e-bikes compared to the other real-world laboratories. However, with a total of 34% of rentals completed on an e-bike, this figure is still significantly lower than the e-scooters, which are also clearly preferred in Erkner. To further examine the extent to which the higher usage rate of e-scooters is related to the actual user preferences, the question of preference was integrated into the survey. This included the question of why one vehicle type was preferred over the other. The surveys in the three real-world laboratories also confirmed the findings described above. All surveys revealed a preference for the use of e-scooters. Depending on the real-world laboratory, roughly 60% or users preferred this type of vehicle (see Image 17). It also shows that only a small share of users make no difference which vehicle is used. Only in Zehlendorf is the indifference between the two vehicle types slightly higher at around 25%. In Erkner, the survey results (35% e-bike preference) also confirm the preferences measured by usage. Representative conclusions can therefore be drawn regarding the preference for an e-scooter over an e-bike. The reasons are varied and overlap in some cases (see Table 12).

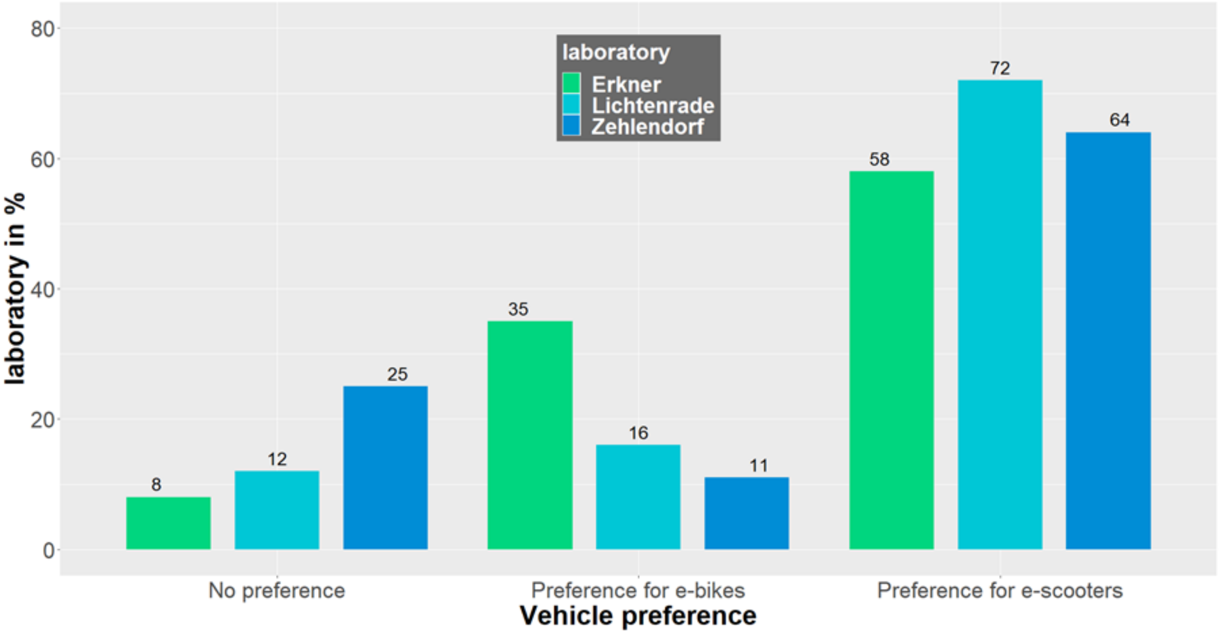

Image 17: Breakdown of responses on vehicle preferences (n = 199)

When providing their reasons, several options could be selected. Table 12 and Table 13 summarize the respective proportion of users and the reasons why they chose the various vehicles. First and foremost, the perceived driving experience (driving comfort + driving properties) is decisive when choosing an e-scooter. From the perspective of many users, passive mobility when using an e-scooter is also a decisive determinant for choosing this type. Many users felt that this is accompanied by the additional advantage that the seat height does not need to be adjust before starting the trip.

A gender-specific analysis of the vehicle preferences does not result in any significant difference to the results of the cross-gender preferences (see Image 17). Across all real-world laboratories, both 68% of female users and 68% of male users prefer e-scooters. There are also no significant differences between genders with regard to the reasons provided.

Table 12: Proportion of reasons for preferring e-scooters (multiple answers possible)

| **Reasons for using e-scooters** | **Erkner** | **Lichtenrade** | **Zehlendorf** |
|---|---|---|---|
| | **Share in %** | | |
| Greater comfort | 40 | 39 | 59 |
| Better availability | 7 | 82 | 75 |
| No effort needed to move the vehicle | 53 | 69 | 47 |
| No need to adjust the seat | 8 | 47 | 49 |
| Aesthetics/ shape of the vehicle | 33 | 14 | 18 |
| Greater sense of safety | 20 | 10 | 10 |
| Higher speed | 13 | 31 | 20 |
| Better driving properties | 33 | 33 | 22 |

### 4.3.2. E-bikes

This contrasts with the significantly smaller number of users who prefer e-bikes, for example due to the configuration options with regard to the desired seat height or basket use. For risk-averse people in traffic, the e-bike appears to be the safer option. This is because a significantly higher proportion of responses for this type of vehicle assign a higher perception of safety when riding an e-bike. As with e-scooter users, there are also users of e-bikes who state a high level of riding comfort and better riding properties as the reason for their preference. This shows that the different inherent characteristics of the two vehicle types each serve the needs of different user groups.

In comparison to the cross-gender trend, there is no significant difference in the preference for e-bikes when differentiated by gender. However, there are slight deviations between the genders in the overall sum of all real-world laboratories. A total of 23% of female users and 15% of male users classify e-bikes as their preferred vehicle. While the perceived higher level of safety and greater riding comfort on an e-bike are the most important factors for female users, male users most frequently state that the e-bike's higher speed is what matters most.

Table 13: Proportion of reasons for preferring e-bikes (multiple answers possible)

| **Reasons for using e-bikes** | **Erkner** | **Lichtenrade** | **Zehlendorf** |
|---|---|---|---|
| | **Share in %** | | |
| Greater comfort | 67 | 27 | 40 |
| Better availability | 11 | 20 | 20 |
| More active means of transport | 0 | 27 | 10 |

| **Reasons for using e-bikes** | **Erkner** | **Lichtenrade** | **Zehlendorf** |
|---|---|---|---|
| | **Share in %** | | |
| Adjustable seat | 33 | 13 | 30 |
| Aesthetics/ shape of the vehicle | 0 | 07 | 00 |
| Use of the basket on the e-bike | 44 | 07 | 10 |
| Greater sense of safety | 67 | 07 | 40 |
| Higher speed | 33 | 40 | 10 |
| Better driving properties | 44 | 07 | 30 |

### 4.3.3. Conclusions

Concerning the preference of the vehicle types studied (e-bikes and e-scooters), it is apparent that users prefer e-scooters under the same conditions. Nevertheless, there is also a significant group of users who are rather drawn to e-bikes. It can therefore be concluded that providers should continue to provide both vehicle types, as long as they are economically viable (though with a higher proportion of e-scooters).

This demonstrates that Thesis 5 formulated for the choice of vehicle types (see Chapter 2.3) can be confirmed. Although the survey provides initial insight into why users prefer to use e-scooters, further research is still needed to exploit the maximum potential of e-scooters. To this end, it is particularly important to address those groups who may be skeptical about bicycles for socio-cultural or practical reasons in order to encourage them to switch to eco-mobility.

## 4.4. Pricing models

This chapter analyzes and classifies the effect of the various pricing models and price increases on usage behavior. The different pricing models are considered separately.

### 4.4.1. Incentivization

**Incentive function through free minutes for intermodal use without recognizable effect.**

It was found that the tested incentive system (three free minutes at the end of the trip at an S-Bahn station in Lichtenrade) to switch to the S-Bahn train system had no discernible effect: the distribution of journeys ending at the S-Bahn stations in the real-world laboratories showed similar values to all real-world laboratories. Every fourth to fifth journey in station-based systems ends at the S-Bahn stations. In addition, the distribution of trips starting at the Lichtenrade S-Bahn stations is almost identical to the distribution of journeys ending there. This is the case even though at the start of the project there was no incentive for users to park their vehicles at the S-Bahn stations (see Table 14).

Table 14: Impact of prices on the duration of use and distance (*progressive price in Zehlendorf)

| **Price per minute [€]** | **Erkner** | | | **Lichtenrade** | | | **Zehlendorf** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Number of trips** | **Ø Trip duration** | **Ø Trip length** | **Number of trips** | **Ø Trip duration** | **Ø Trip length** | **Number of trips** | **Ø Trip duration** | **Ø Trip length** |
| 0.14* | 13,461 | 7.1 | 1.5 | 2,702 | 10.1 | 2.3 | 7,763 | 6.8 | 1.6 |
| 0.19 | 38 | 9.6 | 1.8 | 19,420 | 9.3 | 2.1 | 13,328 | 8.6 | 1.8 |
| 0.22 | 1,311 | 6.8 | 1.6 | 11,335 | 6.6 | 1.6 | 7,734 | 6.5 | 1.5 |
| 0.24 | 0 | / | / | 3,358 | 6.6 | 1.6 | 1,304 | 6.7 | 1.6 |
| 0.26 | 1,881 | 6.5 | 1.5 | 5,823 | 7.3 | 1.8 | 2,933 | 6.8 | 1.7 |

This double comparison makes it apparent that free minutes do not have any additional effect on a switch to the S-Bahn train. This leads to the conclusion that there is a certain proportion of users who travel to the S-Bahn in any case (or begin their journey there), regardless of the real-world laboratory. This is in line with the provider's assessment that controlling the destination by awarding free minutes has at most a minor impact.

Consequently, the allocation of free minutes does not tend to promote intermodal use between sharing services and the S-Bahn train system. Steering prices thus does not appear to be effective in the pricing range of three free minutes as studied. Different minute prices also had no significant influence on the proportion of trips that started or ended at an S-Bahn station. In the price range tested, none of the prices set therefore acted as an incentive to switch to the S-Bahn to a greater extent than is already the case.

### 4.4.2. Progressive pricing

Progressive pricing also did not have the expected effect on usage behavior of reducing longer journeys and increasing the switch to public transport. Doubling the price therefore has no decisive influence on reducing the duration of use. A comparison between Erkner and Zehlendorf shows only minimal differences in the distribution of the duration of all trip - despite the doubling of the price per minute in Zehlendorf (Erkner 0.14 €/min, Zehlendorf 0.14 €/min + doubling of the price from the 13th minute). In comparison with the trips in Erkner, there were even around two percent more trips in Zehlendorf over the fixed number of minutes. Progressive pricing therefore did not result in a reduction of longer journeys.

### 4.4.3. Lower and regular price

**A gradual increase in price did not lead to a reduction in use, but users rated the price very differently**

In order to reflect the market-based prices in the core Berlin operating area in one of the real-world laboratories, the prices in Lichtenrade were gradually increased in parallel to the regular prices in the rest of the city. In the pricing model with a low price in Erkner, this step was only taken in the final weeks of the project in order to assess how demand reacts to a quick jump in prices after a longer acclimatization period. However, since the low price was far below the provider's regular price in percentage and it became clear that continuing the service in Erkner would be very difficult to continue economically, the price was increased to €0.26 per minute for the last few weeks (from mid-April 2023), This was done in order to test usage behavior under regular price conditions. Comparative analyses of usage per day in all real-world laboratories show that the price increases have not led to fewer journeys on average. A similar trend was also evident in Berlin’s city center after the introduction of the sharing service there in 2021 (see Appendix 1: Development of trips per day). Only the average duration of use per trip fell slightly in all real-world laboratories as a result of the price increase (see Appendix 2: Boxplots for trip duration per price). From a price of €0.22/min, a very similar distribution of trip duration and trip distance was observed in all real-world laboratories (see Table 14).

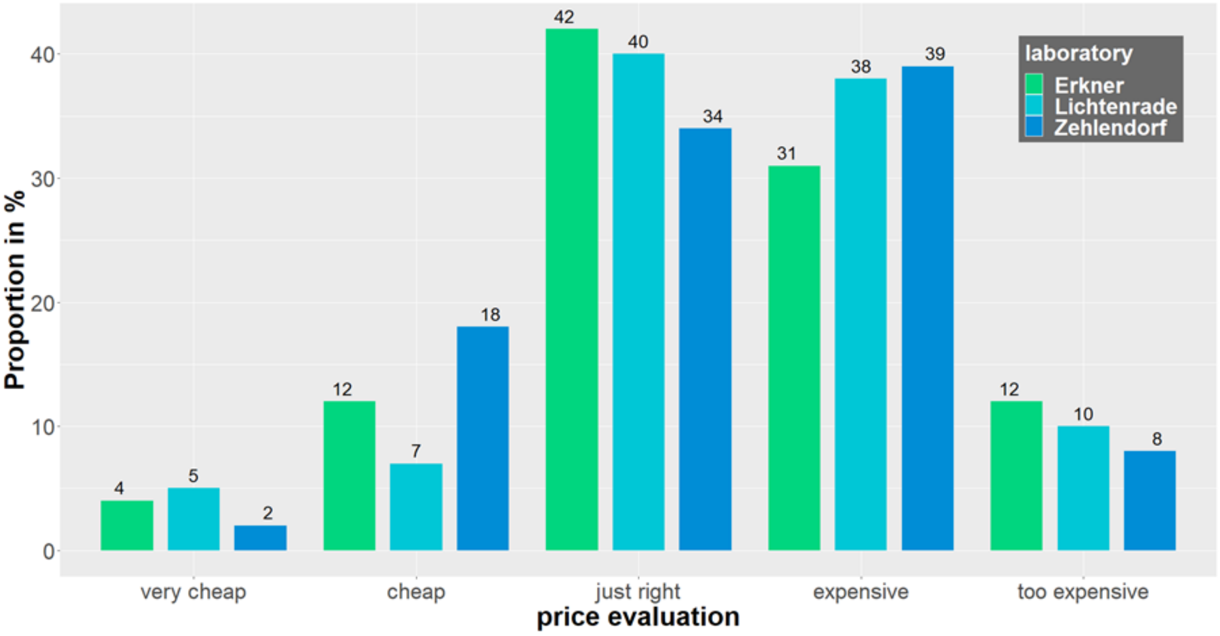

Image 18: Breakdown of responses on the price assessment of the sharing offer (n = 199)

In the course of the study, users were occasionally notified of price adjustments via a push notification before the rental process. In some cases, however, only the price per minute after price adjustments was displayed in the user interface in the app. Even with the significant increase in the price per minute from €0.14 to €0.26/minute, including information via push notification, this did not result in fewer trips being made, but in fact led to a further increase. At a price of €0.14/minute, 63.8 trips were made per day and the average journey time was roughly seven minutes. After the interim increase to €0.26/min, around 68 trips were made per day and the average journey time totaled 6.6 minutes.

This contrasts with the users' assessments of the price, which varied relatively widely within the real-world laboratories but were similar from one real-world laboratory to the next (at the time of the survey, the price was €0.26/min in all real-world laboratories). Depending on the real-world laboratory, 34-42 % of respondents stated that the price was exactly right. This contrasts with 42-48 % who rate the price as at least expensive or too expensive (see Image 18).

### 4.4.4. Conclusions

The results reveal that the different pricing models have no significant impact on steering users towards increased intermodal use of the sharing service. The price incentives for switching to the S-Bahn train did not have a decisive effect. The demand for intermodal use with public transport is high anyway (cf. Chapter 4.2) and is therefore difficult to increase with small financial incentives.

Based on the results of the pricing models, Thesis 4 (see Chapter 2.3), namely an incentive effect to increase the use of micro mobility in combination with public transport through pricing or station models, cannot be confirmed in the context of this study. In particular, the lack of effectiveness of incentives as a drive for increased transfer at S-Bahn stations shows that there is already a high demand for the sharing offer as a feeder to public transport. During the course of the project, both transport services could be used separately.

According to the survey conducted, willingness to pay is heterogeneously distributed among users. Nevertheless, usage did not decline overall after the price increase (see Appendix 1: Development of trips per day). The average usage per day does not reveal any strong price sensitivity among users, although many in the survey rated the service as too expensive. Usage per day in Erkner did not fall after the price increase of around 86% and even rose slightly above the average usage across the entire survey period. This can be seen as an indication of an already established usage among certain users in Erkner.[4] This should definitely be taken into account when assessing the economic viability of operating a sharing service in areas on the city outskirts with a low population density.

## 4.5.Station models

It is widely known that much of the push-back to sharing vehicles, especially from non-users, is sparked when they are parked on sidewalks. For this reason, this study examined how users accept the different parking systems and how the station models corelate to the number of parked vehicles that are parked in such a way that they affect other road users. The summarized view of all interviews also reveals that the design of the parking of sharing vehicles is mentioned and perceived as a central task by all stakeholders. In addition, the interviews increasingly reported an initial volume of complaints after the launch of sharing systems in all real-world laboratories. This resulted in additional staff costs for both the local authority and the provider. According to the experts, direct contact between the so-called public order office ("Ordnungsamt"), traffic planning department and provider is essential in order to resolve complaints and conflicts with illegally parked vehicles in a prompt manner. To this end, the responsibility at the municipal level for citizens' concerns must be clarified in order to be able to swiftly deal with inquiries and problems.

### 4.5.1. Free-floating system

To evaluate the free-floating system, the record of parking violations in the real-world laboratories (see Chapter 3.4) is primarily consulted, as users in this system tend to park their sharing vehicles in such a way that other road users, especially pedestrians, are impaired.

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[4] In this context, it should be noted that other latent factors such as weather conditions can influence usage. These were not considered here.

Image 19: Sidewalk widths in the real-world laboratories (Lichtenrade left, Zehlendorf right), own illustration according to CityLAB Berlin & ODIS, 2023

In Zehlendorf, the proportion of parked vehicles that did not comply with the remaining pavement width of 2.30 m was the highest at around one third. One reason for this is the at times very narrow sidewalk width in Zehlendorf. As a result, even vehicles parked on the edge of the sidewalk fall below the requirements of the special use regulation. Image 19 shows the width of the sidewalks in the real-life laboratories in Zehlendorf and Lichtenrade.

The majority of the sidewalks are no wider than 2.9 m. This means that there is not much space left for sharing vehicles to comply with the requirement of a clear remaining pavement width of 2.30 m (see Image 20). If a micro mobility service is to be promoted, particularly in the outer districts and municipalities on the outskirts of cities, a requirement to maintain a remaining pavement width of 2.30 m, especially in the free-floating system, is not expedient.

Image 20: Parking on narrow sidewalks in Zehlendorf

### 4.5.2. System with virtual stations

The system was tested with virtual stations in Lichtenrade. In absolute terms, the most trips were made here as part of the real-world laboratories. In principle, there was no evidence of a negative impact of station-based parking systems on the use of the service. Therefore, this system does not represent a general barrier to use, but must be examined at this point for a more precise classification based on further criteria.

In this system, the virtual rental and return stations are only recognizable on the map in the mobile app. The survey revealed that the virtual stations are not clear for one in five users (see Image 21). What is more, respondents stated that occasionally there was no space for the rented vehicle within the virtual parking area because it was completely occupied by other sharing vehicles. The expert interviews confirm that this system expounds the existing problems of the free-floating system and impedes user-friendliness. As there are no specifications as to how the vehicles should be parked, the space is not used efficiently. This can result in an accumulation of improperly parked vehicles.

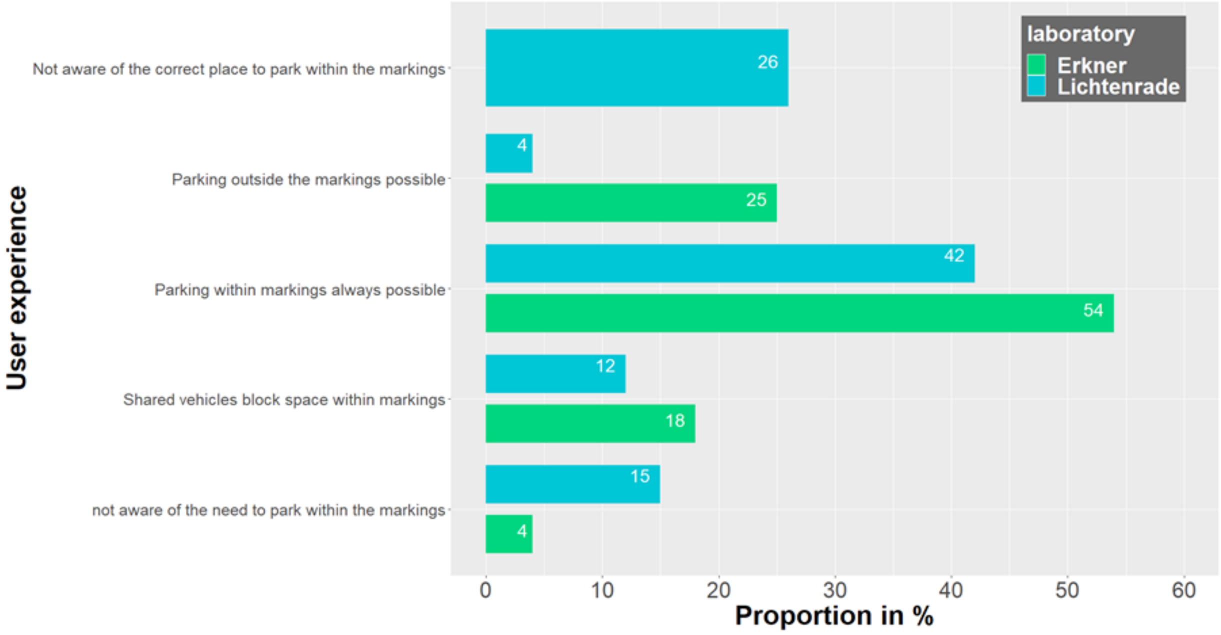

Image 21: Breakdown of responses on user experience (n = 120)

In addition, the survey responses also show that the chosen location of the stations is rated very differently (see Image 22). In Lichtenrade in particular, the reviews show that compared to Erkner (8%), a much larger proportion rate the location as very poor (21%). Only 10% in Lichtenrade are of the opinion that the site of the stations is very good (compared to Erkner: 15%). A comparison of the source and destination relationships (see Appendix 3: Originating traffic at S-Bahn stations in real-world labs) in the real-world laboratories with station systems shows that the coverage in Lichtenrade is not sufficient to guarantee comprehensive accessibility of the stations within the operating area. In Erkner (which had a higher density of stations than Lichtenrade), the chosen hexagonal division clearly shows that the station density there leads to complete coverage, whereas in Lichtenrade many areas in the operating district show no activity.

During the site inspections in Lichtenrade (06.04.2023 and 07.06.2023), vehicles below the remaining sidewalk width were counted. It was found that the proportions in the station-based system were similar to those in the free-floating system. Shortcomings can be detected once for around one in four vehicles and once for around one in three vehicles. Virtual systems therefore have a similar deficit to free-floating systems in terms of the orderly parking of vehicles.

As in the free-floating system, the problem of narrow sidewalk widths on the outskirts of the city is an additional complication. For the station systems, in addition to the remaining pavement width, it was also determined whether the vehicles were parked within the stations. Despite the relatively large virtual stations, relevant proportions of vehicles (15% and 6%) were observed in Lichtenrade during both surveys that were parked outside the stations.

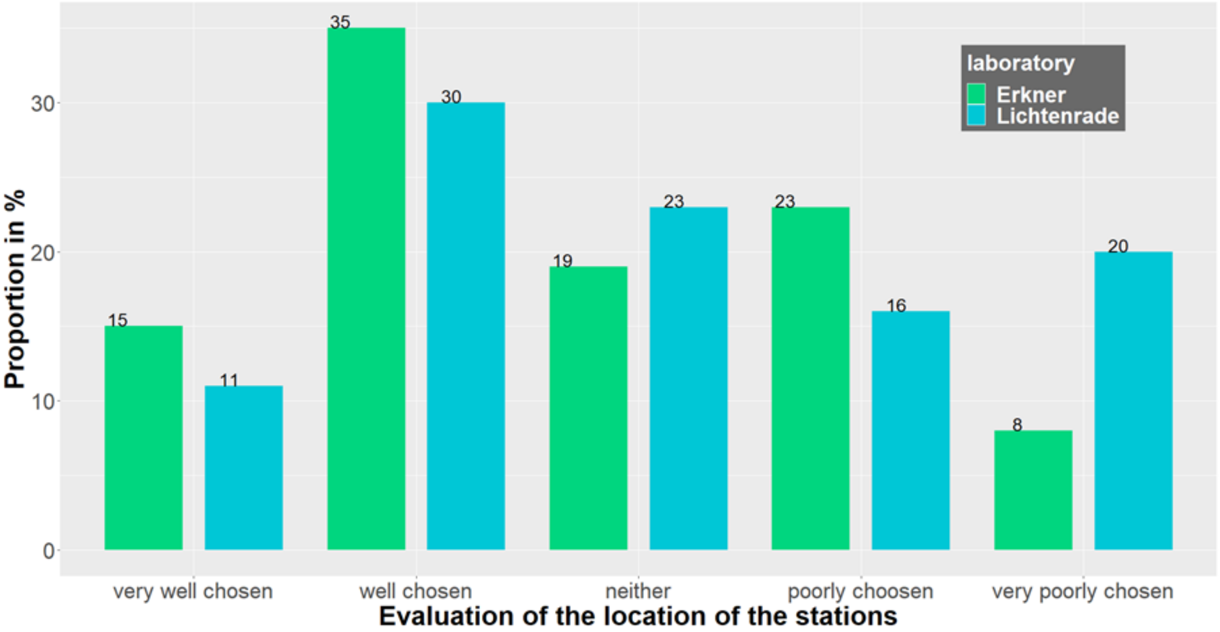

Image 22: Breakdown of assessments of the station location (n = 119)

### 4.5.3. Station-based system with ground markings

By comparing the two station systems, the effect of different station densities on user satisfaction can be analyzed. In both real-world laboratories with station systems, users stated that there were too few stations and the distance between these was too great. In Erkner, around 20% of respondents stated that there were too few stations overall. In Lichtenrade, this figure was as high as 35% (see Image 23). The station density in Erkner was significantly higher than in Lichtenrade. From the interviews conducted, a close-knit station system, comparable to that of a bus network, also proved to be the optimal solution for the implementation of stations. This should ensure a high level of vehicle availability.

Some respondents stated that the stations were too far from public transport stops. This shows that, regardless of the station density, around one in ten respondents would like to see a better connection between the stations and public transport stops.

Overall, in the physical station-based system in Erkner, the fewest vehicles were observed that fell below the remaining sidewalk width. The proportions in the three surveys are 1-8%. In Erkner, the proportion of vehicles parked outside the stations is slightly higher than in Lichtenrade. On 03.03.2023, in addition to the borders, pictograms depicting a scooter were placed in the middle of the parking areas to make it clear that these areas are reserved for returned sharing vehicles. Before the pictograms were introduced, the proportion of vehicles parked outside the areas was 15% of all vehicles; after their introduction, it was 21% and 7% respectively. Consequently, no effective control is possible through the pictograms, which make parking inside the stations more likely.

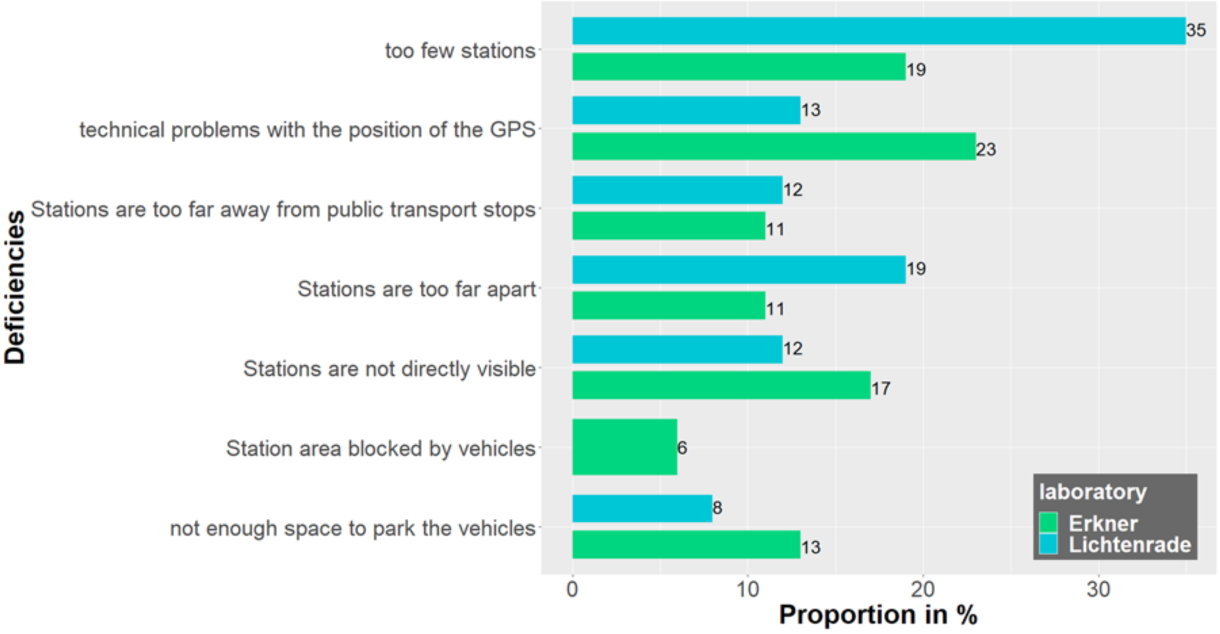

Image 23: Breakdown of assessments of the station quality (n = 120)

However, the aforementioned issues with GPS inaccuracy should also be noted here. In Erkner in particular, the limited station area meant that a comparatively high proportion of respondents had problems finding their position using the GPS signal. In that area, it was possible for one in four people to park their vehicle outside the perimeter. The experts made it clear that it is important to provide information about the inaccuracies of GPS technology. This way, a large number of vehicles parked in violation of the rules could be avoided (see Image 24).

Image 24: Parking examples in the operating area in Erkner

Furthermore, the demarcated areas are repeatedly blocked by vehicles parked there (third-party use) (see Image 25). The pictograms cannot effectively prevent unauthorized use. During inspections, third-party use was observed at stations with and without pictograms.

Image 25: Examples of conflicts with cars on stations on the street in Erkner

### 4.5.4. Conclusions

The investigations into the three different station systems revealed very interesting findings with regard to integration into the existing transportation system.

While the free-floating system offers a great deal of flexibility for users on the one hand, it has also been shown that this system poses the greatest risk in terms of disruption to other road users due to poorly parked vehicles. Despite the inherent potential for conflict with pedestrians, free-floating systems can be an advantageous option in certain constellations. A free-floating system can be implemented more quickly and saves on staff time for municipalities and providers. The design of the chosen solution for parking vehicles can therefore generally be seen as the greatest leverage for the necessary personnel costs.

The system with purely virtual stations poses the same challenges as the free-floating systems in terms of parking the vehicles. However, it also means even greater uncertainty for users regarding the desired parking behavior. When returning vehicles at purely virtual stations, users are often unsure where exactly the station area is located or how exactly they should park their sharing vehicles so as not to inhibit other participants.

The system with virtual stations, which are supported by floor markings (border and pictogram) and physical barriers (e.g. traffic guide beacons), resulted in the lowest incorrect use. Physical barriers can prevent unauthorized use and users feel much safer dropping off their sharing vehicle within the marked areas. Although the implementation of pictograms has proven to be ineffective against third-party use, they should still be used to support and visualize the service offer. It is important to create physical barriers to effectively prevent unauthorized use. In addition to the pictogram, a sign could be erected to further increase visibility. The findings also show that a station-based sharing system must come with a high density in order to ensure high availability for users. However, the implementation of a station-based system is associated with costs for both the municipality and the provider. Municipalities in particular often do not yet have sufficient capacity for the tasks required to introduce a station-based system.

Regardless of the type of station system, it is evident that a high station density should be maintained in order to offer high availability of the service across the entire operating area. Analogous to the conclusions in Chapter 4.2.3, it can be deduced from the fact that for some users there is a lack of proximity of the stations to public transport stops that these should be located closer to the stops.

The design of the parking system also had no effect on the frequency of combined use of the sharing system and local public transport, which mainly occurs in combination with the S-Bahn train system, regardless of the station model. A significant finding in this context is that station-based systems, provided they are well designed, are neither a barrier to use in general nor to linking with public transport. Based on the results of the station models, Thesis 4 (see Chapter 2.3) cannot be confirmed in the context of this study.

# 5. Recommended actions

Based on the previous findings, the following recommendations for the launch and operation of a sharing system in outer districts and small municipalities can be made: 1. recommendations for municipalities, 2. recommendations for sharing providers and joint recommendations that should be implemented by municipalities and providers in tandem.

## 5.1.Recommended actions for municipalities

**Good communication as an accompanying measure**

Targeted and early communication is necessary to achieve the highest possible level of acceptance among the general public, users and employees in local government, which can have a significant impact on the success of the launch of a new sharing service.

- Motivation and early involvement of staff from the municipality: Open communication about potential issues and additional tasks that may arise appears to be expedient in order to increase and ensure motivation for dealing with new, additional and possibly unexpected tasks. First and foremost, the local public order office (“Ordnungsamt”) should be properly involved, as it faces the possible effects and complaints, especially due to (presumably) incorrectly parked vehicles. It is also an important point of contact for the sharing provider. Beyond the project framework, a fixed budget for additional personnel resources should be proposed. It may also be necessary to restructure the existing tasks of municipal employees.
- Open, transparent communication with citizens in the new operating areas: From a municipal perspective, early communication and the naming of possible initial problems ("teething troubles") can prevent complaints from arising. In addition, the objectives associated with the new service and the advantages that sharing services can bring should always be explained in order to create a general interest in the sharing service among the population. For example, target group-oriented campaigns or communication strategies are suitable for sharing services (see Tils et al., 2015).
- Establish digital communication channels: It is only sensible for municipalities to establish digital communication channels in order to potentially reach more citizens with less effort. Digital media or even social media communication channels can be efficient and effective. However, older people in particular, for whom the use of rental systems is hardly an option and for whom vehicles that are improperly parked can be an obstacle, are very difficult to reach via these channels. Information should therefore continue to be shared via all available communication channels.

**Integration of micro mobility into the municipal transport policy strategy**

The sharing service should be considered as an integral part of a municipal public transport service. Here, for example, it makes sense to integrate the service objectives into the transport policy strategy and use them as a clear basis for argumentation, as recommended in a report by the German Institute of Urban Affairs (Difu, 2022).

Micro mobility can act as a complementary mobility offer to a stretched public transport service. In contrast to public transport, the operation of sharing systems is not tied to people. Sharing systems can therefore also be included in the route planning of users as a permanent mobility service at times when there is no public transport service (at night). This shows a possible financial advantage in the sharing offer. Due to low capacity utilization, the operation of bus routes can cause relatively high personnel costs at times of low capacity utilization (cf. Kupper et al., 2010).

This is where the sharing system can come in and create appropriate availability at off-peak times in order to further increase the attractiveness of eco-mobility. Shared small electric vehicles and e-bikes also have advantages in terms of $CO_2$ emissions compared to a bus with few passengers. While local buses emit 93g of $CO_2$ per passenger kilometer (cf. laut Umweltbundesamt, 2022), modern e-scooters emit between 40 and 50 g per passenger kilometer according to life cycle analyses by the providers (cf. Bolt, 2023). This circumstance makes it clear that consideration should be given to whether sharing services should be integrated as a component of local public transport in the future.

**Develop in-house expertise: Documentation for internal and external stakeholders**

The initial introduction of a sharing service can be initiated by a committed individual in the local office. In the medium and long term, it is advisable to anchor planning and supervision institutionally rather than on an individual basis. Therefore, approaches to solutions and the knowledge generated about sharing systems should be documented in order to build up an internal knowledge base. This knowledge can also be made available to interested municipalities, such as neighboring municipalities. Here, it makes sense to create and share guidelines.

In addition, local authorities’ existing knowledge of local structures can be made available to providers in order to develop targeted solutions. Broad prior knowledge offers great potential for saving resources when setting up the station systems, both for the provider and for the municipality. Accordingly, it is recommended that the provider discusses potential station locations with the municipality in advance in order to incorporate the existing local knowledge of municipal employees about areas with potential for conflict.

**Use of mobility dashboards**

Municipalities are advised to use a mobility dashboard from neutral third-party providers in order to get an independent picture of the micro mobility offer[5] and to be able to integrate sharing offers into the municipal transport offering if necessary.

The dashboard can be used to view selected live data from the respective provider's sharing system, such as the location, battery status or last use of the vehicles. Local authorities can then use this data to proactively identify areas where action is needed and develop their own expertise. Examples of mobility dashboard apps include Populus and Vianova, which are specially designed for collaboration between municipalities and mobility service provider.

**Create framework conditions for economical operation**

- During the development of the operating area in a new municipality, it is advisable not to introduce strict regulation so that the provider can gain the necessary local experience for an economically viable tariff structure. In Munich, for example, sharing providers undertake to comply with a regulatory framework set by the city council as part of a voluntary commitment. This includes various specifications for selected areas, including the operating area, the vehicle fleet and parking sites. It regulates, for example, the maximum number of vehicles for prescribed sections within the operating area and a maximum limit of four parked vehicles for defined station sites. In addition, virtual stations with a maximum number of vehicles are made possible. The priority here is to link the virtual stations with the station points defined by the City of Munich (see City of Munich, 2022). The concept in Munich can create a sufficient regulatory framework for the launch of the service (cf. City of Munich, 202222). Based on a comparatively lower economic efficiency, special usage fees should be completely waived or at most charged to a reduced extent in operating areas on the city outskirts with a low usage density in order to compensate for the low turnover or comparatively higher operating costs. A combination of low usage density and special usage fees is hardly financially viable from the provider's point of view. If special usage fees are unavoidable, it is advisable not to charge them, at least not in the initial phase.
- The density of use during the real-world laboratories was significantly lower than in Berlin’s city center, for example. Due to the low turnover, the provider would move the vehicle fleet to a denser operating area purely from a private-sector perspective in order to generate higher revenues there. Various alternatives could be considered as compensatory solutions to minimize costs and improve planning reliability for the provider, which should ideally be bundled together:
    - Financial grant/compensation (subsidy) by the municipality in the event of loss-making operation in order to realize the potential of the sharing offer for sustainable, flexible and readily available mobility. The sharing service should not be seen as an additional source of income, as was the case for some Berlin districts in the past according to Gersch et al. (2021).

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[5] Clear browser-based display of current vehicle locations and usage intensity as well as complaint management

- Introduce ordered services to create a temporary offer under clear financial conditions. This may not be necessary at the start, but should be considered as an option after initial experience in the municipalities.
- Integration of the sharing offer into the local public transport system, which can have a multifactorial effect: Improving and facilitating links with public transport and consequently a higher expected demand.
- Inter-municipal cooperation: depending on the geographical location of the neighboring municipalities, this approach can be worthwhile both financially and in terms of transport. Especially if the only connection to the rail network in the vicinity is in one of the participating municipalities and the sharing system enables access to the rail network for the population of the municipalities without a train station.
- The operation of a local "micro" warehouse to reduce the distances involved in replacing batteries, regular maintenance, etc. would be a conceivable solution to reduce operating costs. It would make sense to support the provider in the search for a suitable site and, if necessary, to offer discounts.

## 5.2.Recommended actions for providers

**Variations of the price per minute and incentives at the start of the offer**

An intelligent penetration strategy appears to make sense for launching the sharing service to new operating areas. For example, potentially interested citizens could initially be attracted by a low price in order to later improve the economic viability of the service by successively raising the price. In addition, another study has shown that e-scooter users are not as price-sensitive if the service is used as a quickly available mobility alternative (see Aarhaug et al., 2021).

The provision of free rides or free minutes as an incentive at the beginning of the service could serve as a solution strategy in the event of prolonged inactivity of a registered user, as also recommended by Koska et al. (2021). As the incentives to switch to the S-Bahn have not had any noticeable effect, the available funds should be invested in activating and retaining users.

To compensate for economic uncertainties on the outskirts of the city in terms of usage density, subscription models could be introduced for "frequent users" in order to be able to rely on the corresponding income on the one hand and to generate even stronger user loyalty on the other. In Erkner, despite the lowest absolute density, the utilization per user was the highest overall. A financing plan can be drawn up between the municipality and provider on the basis of a calculable amount. The ordering municipality could then cover any shortfall that arises.

**Introduce a combined fleet of e-scooters and e-bikes**

Despite the demonstrated preference for e-scooters, providers are not recommended to focus entirely on e-scooters when designing their vehicle fleet. Instead, they should address the smaller target groups for e-bikes in order to appeal to as large a share of the respective population as possible. It can therefore be concluded that both vehicle types should be provided, if economically viable, but with a higher proportion of e-scooters.

**Ensure combined transportation between micro mobility and public transport**

There should be a comprehensive selection of stations near bus stops in order to further strengthen sharing services as a component of intermodal transportation. Consequently, as an additional need for action for providers, it can be concluded that a high availability of vehicles in stations close to public transport stops is vital.

## 5.3.Recommendations for local authorities and providers

**E-scooters are advantageous in terms of demand and financial aspects**

Clear agreement on the design of the vehicle fleet should be concluded between the provider and the municipality. E-scooters were identified as the preferred vehicle type in the project. Against the background of conflicts of use in public spaces, e-scooters have the advantage that e-scooters take up less space than e-bikes, which leaves more room for maneuvering when identifying suitable station areas. In addition, e-scooters are cheaper to purchase and operate, giving providers greater financial leeway. This will be necessary in the future to operate them economically in small towns.

**Introduce a station-based sharing system**

Taking into account all stakeholders, the implementation of a station-based system can be recommended as the most expedient approach to establishing a low-conflict and reliable mobility service. In the case of station systems, a distinction must be made between the installation on sidewalks and on the street. As part of a combination of push and pull measures, however, it is urgently necessary to rededicate car parking spaces. This will relieve the tense sidewalk situation and significantly reduce the risk of accidents for pedestrians, as the use of small electric vehicles such as e-scooters can also lead to conflicts and accidents on sidewalks (cf. Uluk et al. 2020). The reduction of parking space and parking space management should be seen as a lever for changing mobility behavior (cf. Canzler, 2021). Where possible, the stations should be set up at road junctions for two reasons. First, this has the potential to improve visibility for all road users (cf. Difu, 2022), which can lead to an increase in reaction times in road traffic. Second, this results in good visibility of the station for users compared to a station located between two parked cars.

**Increase station density**

Station-based sharing systems should have dense station networks. In the long term, the establishment of a dense station-based model is recommended, whereby the stations should exhibit a spacing of 100 to 200 m in order to ensure a generally high level of accessibility for all users. The Jelbi ordinance framework concept in Berlin can be cited as good practice in this regard. In addition, proximity to public transport stations should be taken into account in order to facilitate intermodal transfers.

**Ensure clear visibility of the station**

A further requirement is the structural design of the stations. To ensure a high level of visibility, a traffic sign should be installed that precisely describes and identifies the area. It has been shown that the low-threshold station system to be set up in Erkner without traffic signs and comprehensive structural demarcation is not sufficient for permanent operation in order to ensure a functional station infrastructure for users and other road users. One implementation option is to initially set up low-threshold and temporary traffic beacons in order to then be able to observe in practice how the station is accepted and where adjustments may need to be made (see Difu, 2022) in order to make the stations permanent.

**Alternatives to the station-based system: free-floating only as part of a hybrid station concept**

If a nationwide station system is not yet feasible, a hybrid station system is an alternative, whereas the use of virtual stations is not advisable as it does not create a comprehensible framework for users. Hybrid station systems combine the free-floating system with individual fixed stations (see Meng & Brown, 2021). Due to the narrower sidewalk widths, it is advisable to exclude streets with narrow sidewalks from free-floating. However, this clearly conflicts with the objective of providing a comprehensive mobility service on the outskirts of cities. In a hybrid system, stations could be set up at the intersections of narrow streets, at the edge of the road and at locations with high demand (e.g. train stations). Where the sidewalks are wide enough, a free-floating system could apply.

Operation in a free-floating system can be used as a preliminary stage for a station-based system in which data on the movements of users is collected in order to derive hotspots at which a station can ideally be set up in the vicinity.

# 6. Conclusion and outlook

As part of the “NaMikro” project, three real-world laboratories were run in the city of Erkner and in the Berlin districts of Steglitz-Zehlendorf and Tempelhof-Schöneberg for nine and ten months respectively in order to study the extent to which shared micro mobility may be managed and used on the outskirts of Berlin under conditions that resemble those already in practice. The study focused on the use of the sharing offer in combination with public transport. To this end, different pricing and station models were tested and compared with each other as well as with a reference area in the city center of Berlin. For the analysis, mainly the movement data and the renting and parking behavior of the users were analyzed. Surveys of users (n = 204) were carried out as an additional augmentation of the quantitative data evaluation. Qualitative observations were also made during site visits to the real-world laboratories. After the real-world laboratories were completed, seven interviews were conducted with selected experts from different stakeholder groups in order to incorporate their experiences and perceptions in the real-world laboratories into the findings. By combining all of the analysis methods, it was possible to formulate recommendations for action for municipalities and providers for upcoming and ongoing operations of sharing services, especially in outlying districts and locations.

The key findings are:

- In all of the real-world laboratories studied, an increased linking of sharing services with local public transport was demonstrated. Sharing vehicles are primarily used in combination with the S-Bahn train service. There is a clear preference for e-scooters, but it also emerged that there is a specific target group that favor e-bikes.
- In the medium term, a station-based system should be provided for sharing services on the outskirts of the city, at best on the streets, in order to keep vehicles off the sidewalks and at the same time create an additional push factor by removing parking spaces.
- It is possible to substitute car journeys with shared vehicles. However, a sustainable system that is acceptable to all road users should be established in any case.
- Despite the promising findings concerning the role of sharing services in the Transport Transformation, the various neuralgic aspects need to be addressed in order to exploit the demonstrated potential. The biggest hurdles to the long-term viability of shared micro mobility are the orderly parking of vehicles and the cost-effectiveness of operation. Here, the findings from the real-world laboratories lead to the conclusion or recommendation that municipalities should rely on station-based systems in the future. The use of virtual stations is not recommended, as this system causes confusion among users and is also particularly susceptible to parking violations. A free-floating system is often not an optimal solution, especially where sidewalks are particularly narrow.
- Finally, it remains to be noted that in the future, more effort will be needed to create closer links between sharing services and public transport in order to promote shared use. In addition to integrating fares, good cycling infrastructure and low-conflict station systems should also be considered here.

Overall, it becomes evident that various parts of the sharing system are still running parallel to each other, especially during the roll-out phase and are not yet sufficiently interlinked. In future, it should therefore be a priority for local authorities and districts to integrate sharing services into their transport policy strategy. Building on this, the necessary coordination should be carried out in a more targeted manner and clear targets should be set. First and foremost, the intermodal link to public transport on the so-called “first” and “last mile”, the temporal and spatial flexibilization of public transport and the reduction of car traffic on short distances should be targeted in order to achieve a deceleration of traffic, especially in residential areas.

The NaMikro project has provided initial scientific findings on the use of shared micro mobility on the outskirts of cities. Nevertheless, there are still unanswered questions regarding the use and potential of these services, which should be investigated in later studies.

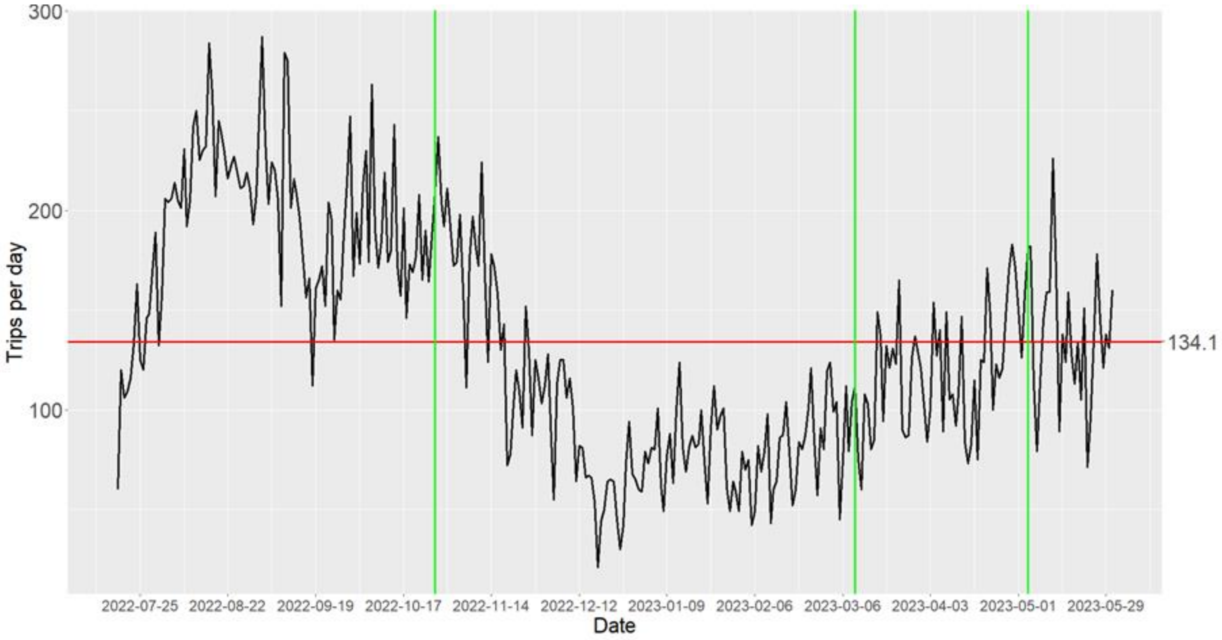
At the end of the project, there are no reliable findings regarding the reasons for one-off use of the sharing service. This question should be included in future surveys and studies in order to discuss the extent to which untapped potential can be leveraged through a targeted offer for target groups that have not yet been addressed.

Despite the model character with different station systems and rising prices, it can be seen across all real-world laboratories that the majority of users use it as an alternative to the car. However, the frequency of use as a car replacement varies considerably in the real-world laboratories. The reasons for this should therefore be examined in subsequent studies. In addition, a demand for the use of the sharing service was also identified for longer distances from the outer to the inner districts and vice versa for the real-world laboratories examined in Berlin. This raises the question of what potential this usage behavior holds for replacing longer car journeys, for example, or whether these longer journeys are more likely to replace public transport.

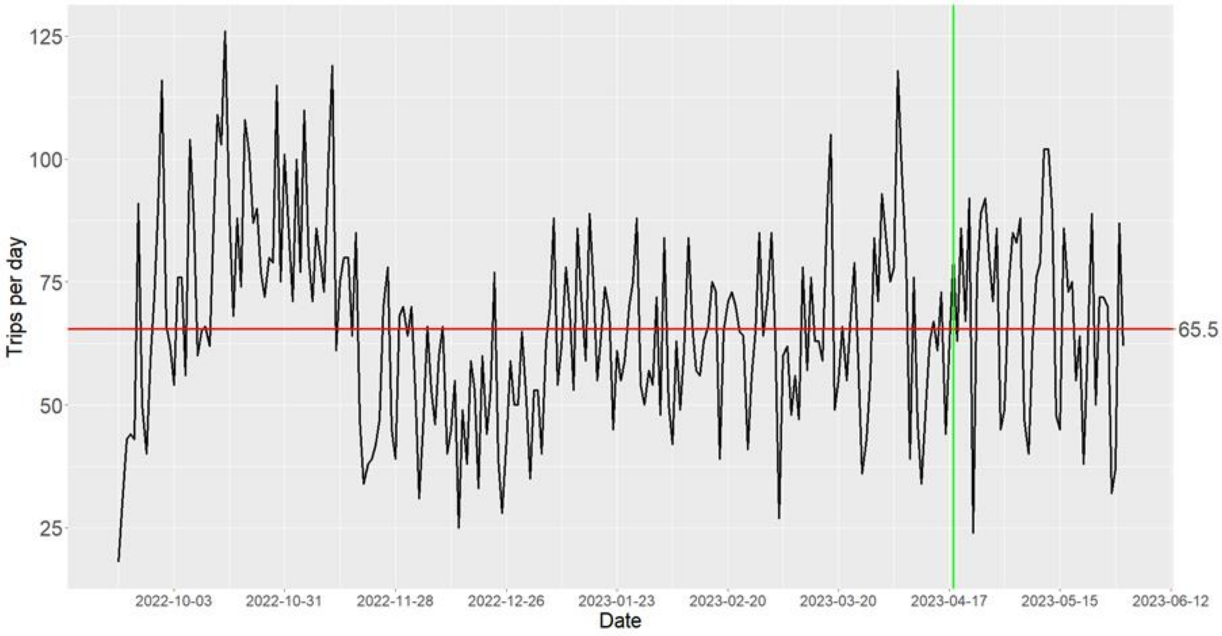
The findings described in this study should be placed in the context of the period of the sharing offer to date. Since the sharing offer in the real-world laboratories has only been in place for a comparatively short time, the question arises as to what extent the sharing offer has already become established in mobility routines. Accordingly, further long-term studies should be carried out that examine changes in mobility behavior following the introduction of a sharing system on the outskirts of the city.

# Appendix 1: Development of trips per day

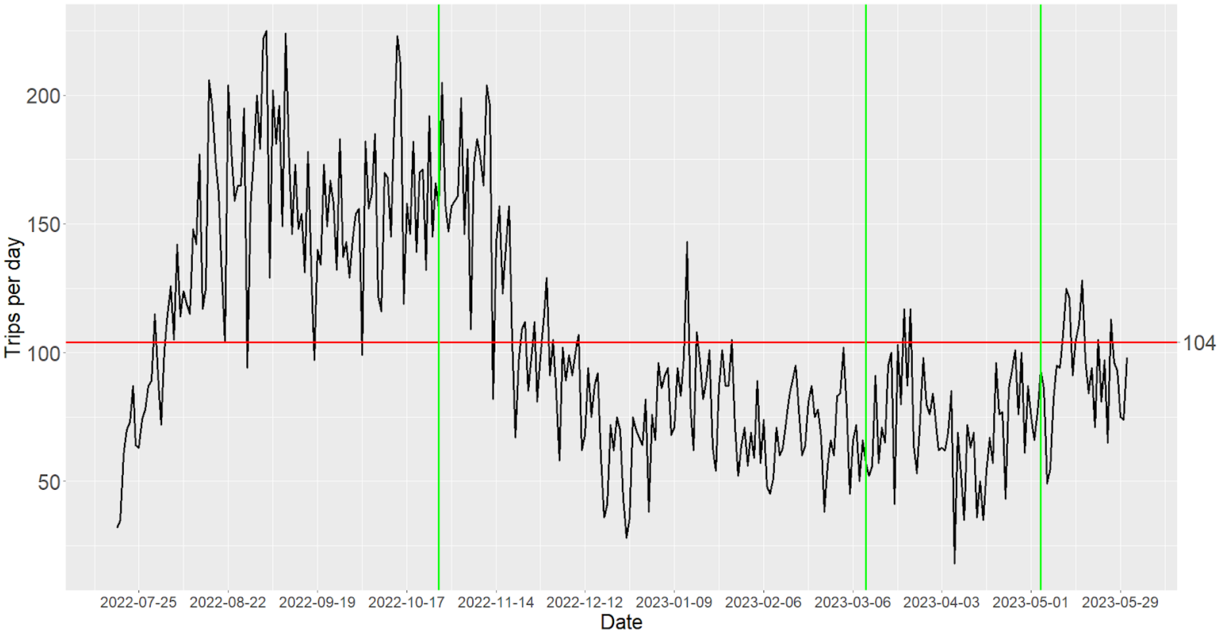
**Lichtenrade**:



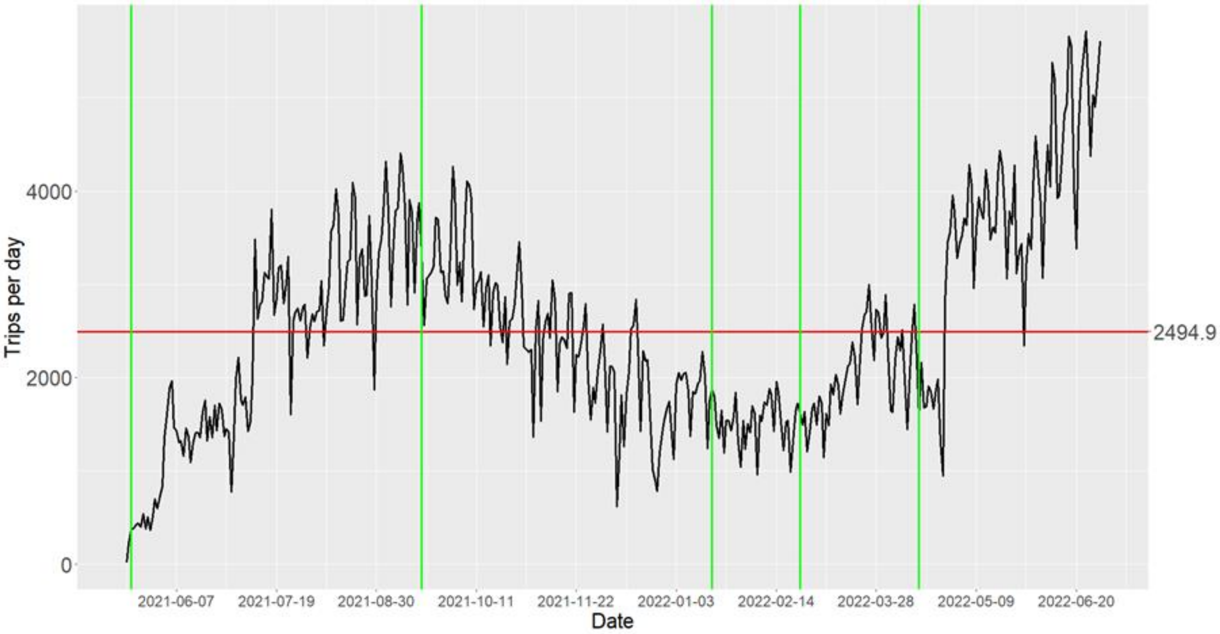
**Erkner**:



**Zehlendorf**:

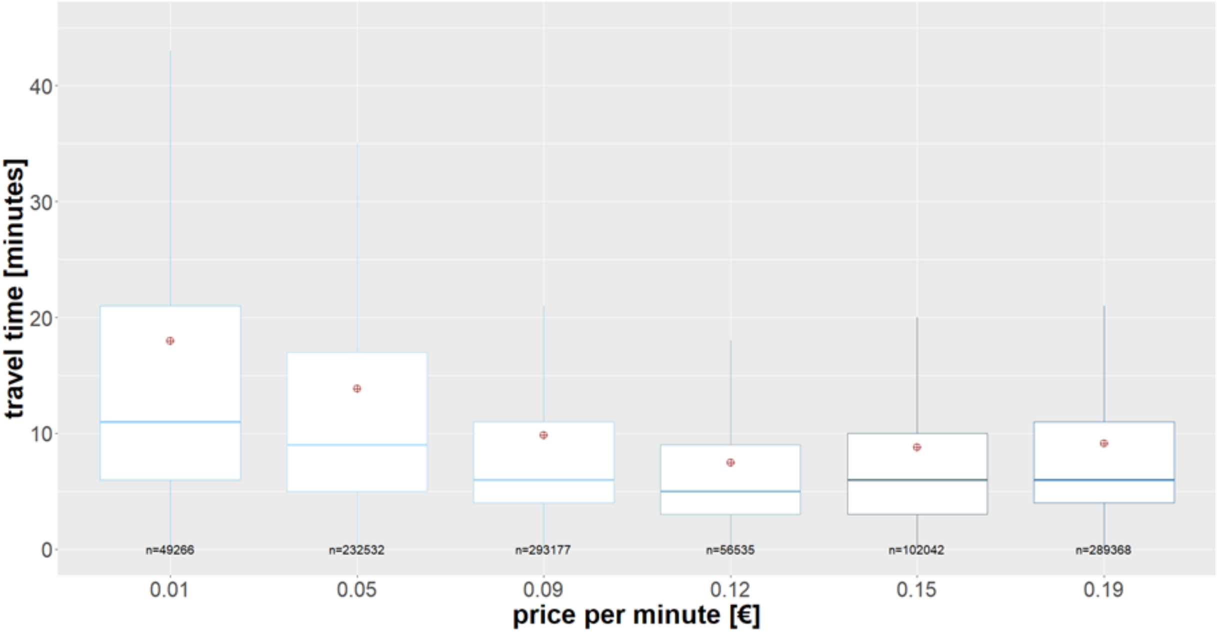


**Berlin**:

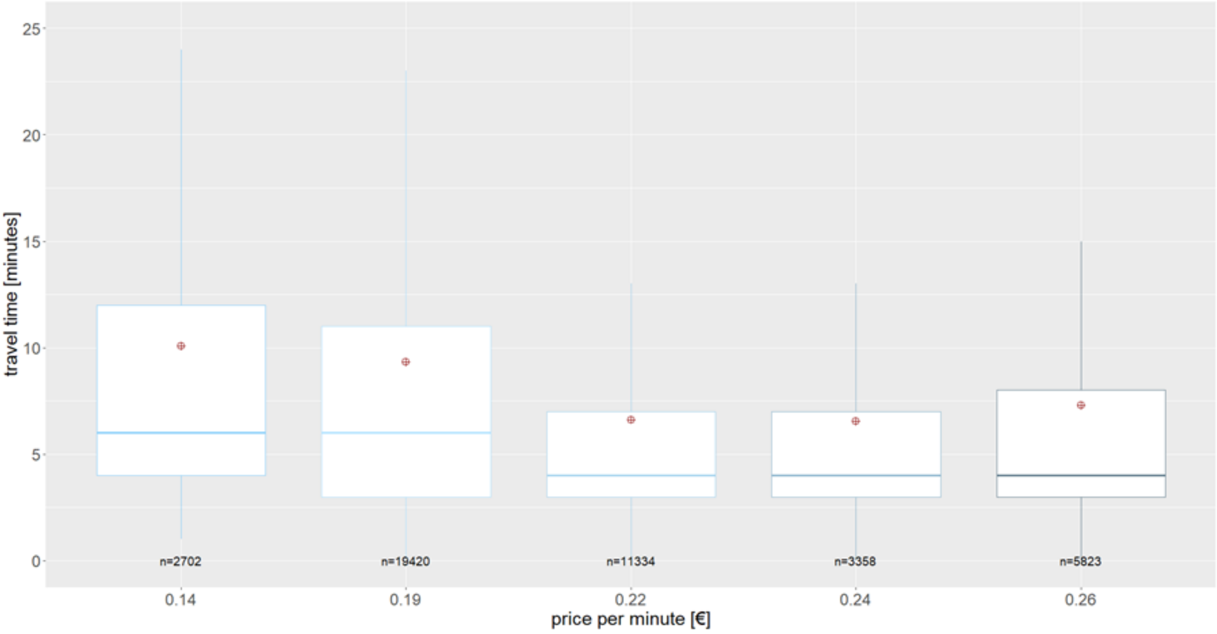


# Appendix 2: Boxplots for trip duration per price

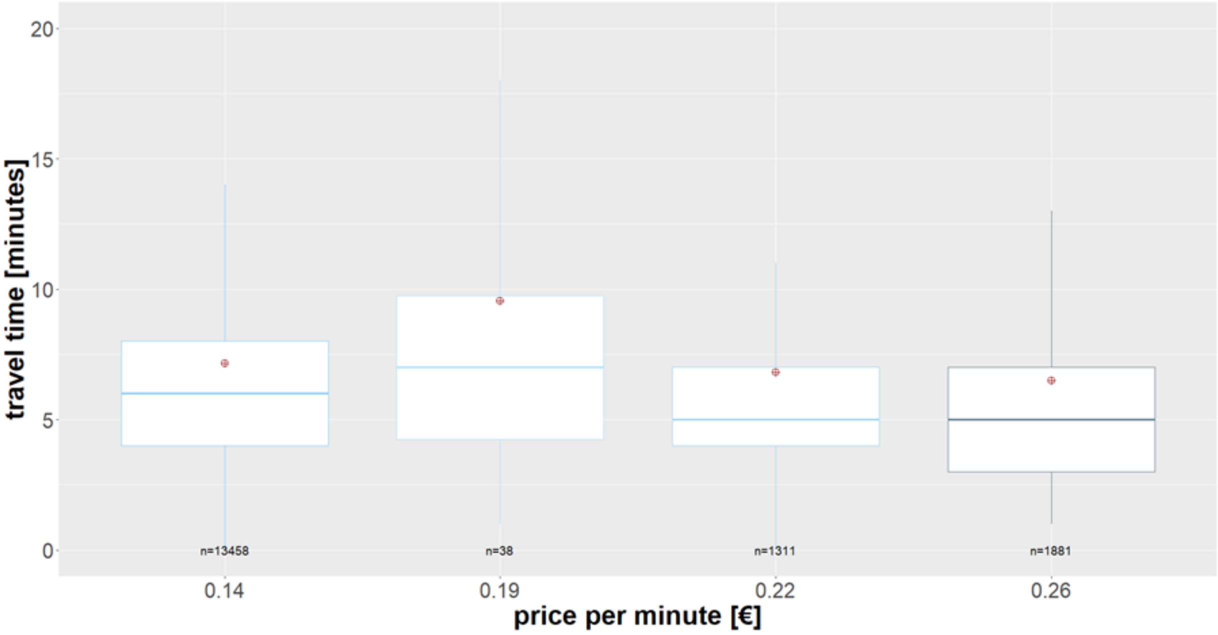
**Berlin**:



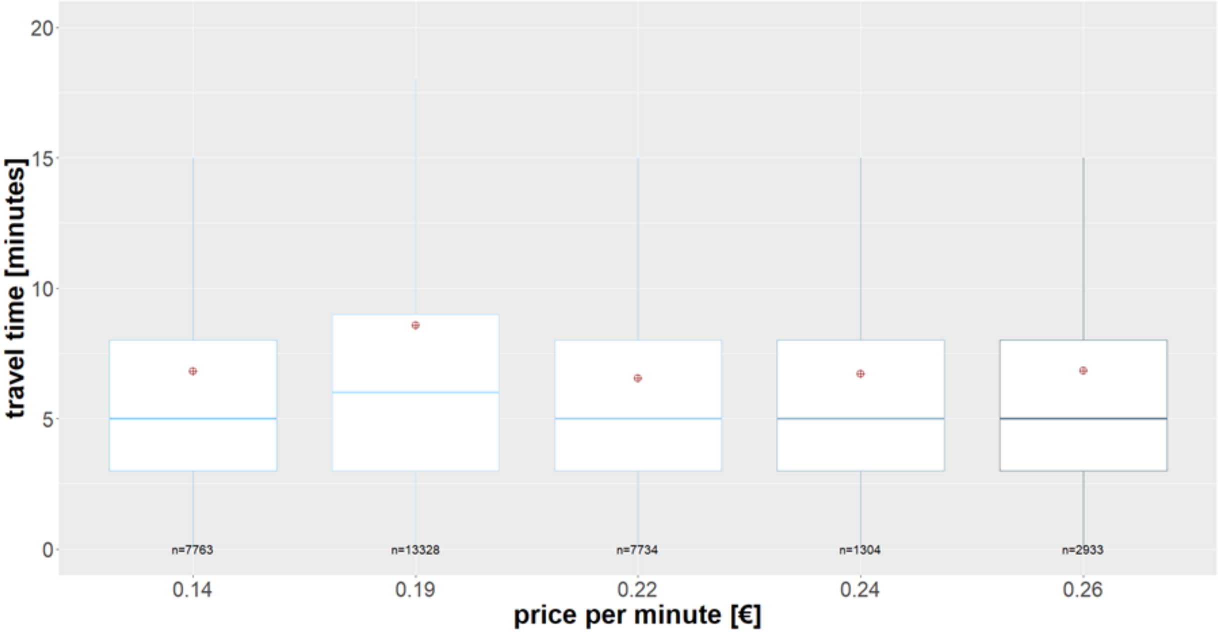
**Lichtenrade**:



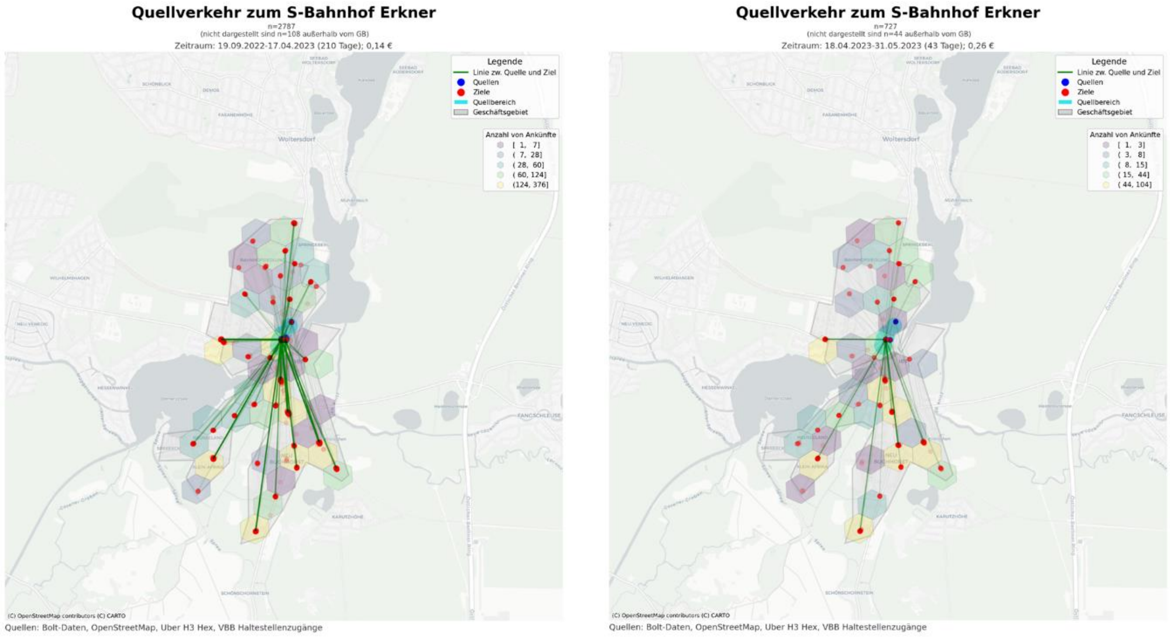
**Erkner**:



**Zehlendorf**:



# Appendix 3: Originating traffic at S-Bahn stations in real-world labs



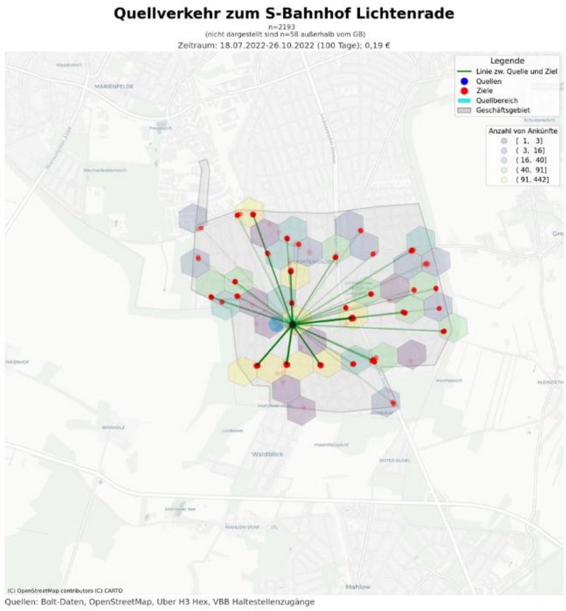
Quellverkehr zum S-Bahnhof Erkner
n=2787
(nicht dargestellt sind n=108 außerhalb vom GB)
Zeitraum: 19.09.2022-17.04.2023 (210 Tage); 0,14 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Quellverkehr zum S-Bahnhof Erkner
n=727
(nicht dargestellt sind n=44 außerhalb vom GB)
Zeitraum: 18.04.2023-31.05.2023 (43 Tage); 0,26 €

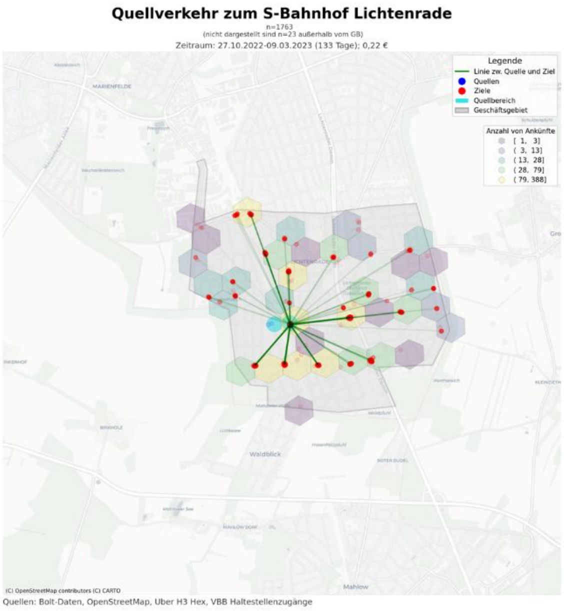
Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Originating traffic at S-Erkner station



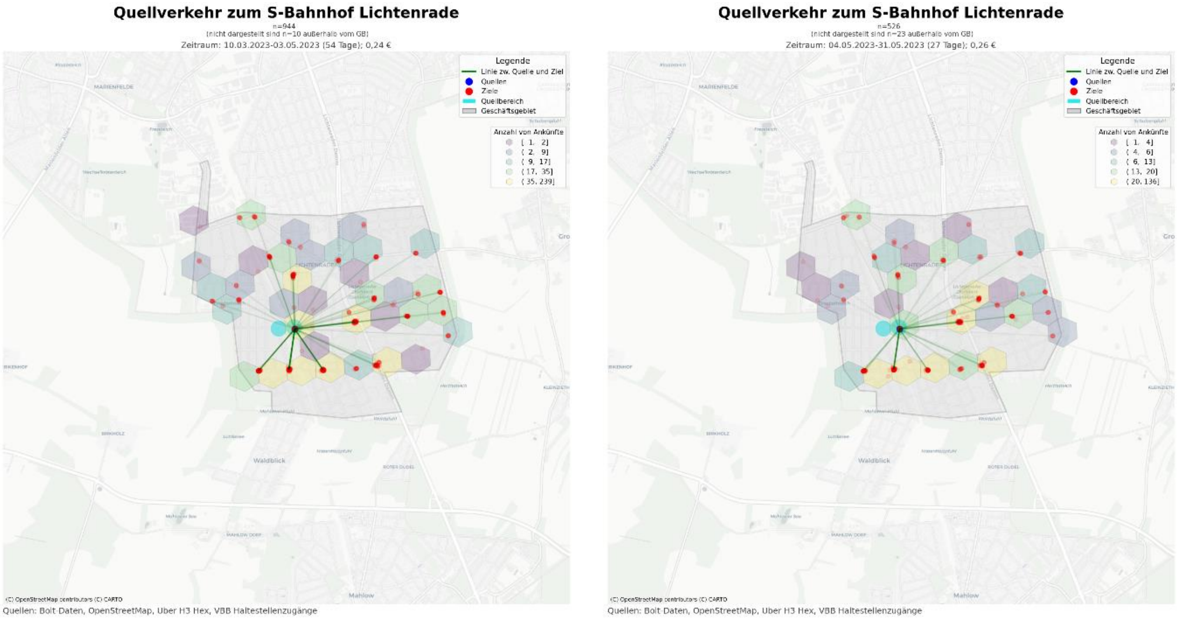
Quellverkehr zum S-Bahnhof Lichtenrade
n=2193
(nicht dargestellt sind n=58 außerhalb vom GB)
Zeitraum: 18.07.2022-26.10.2022 (100 Tage); 0,19 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge



Quellverkehr zum S-Bahnhof Lichtenrade
n=1763
(nicht dargestellt sind n=23 außerhalb vom GB)
Zeitraum: 27.10.2022-09.03.2023 (133 Tage); 0,22 €

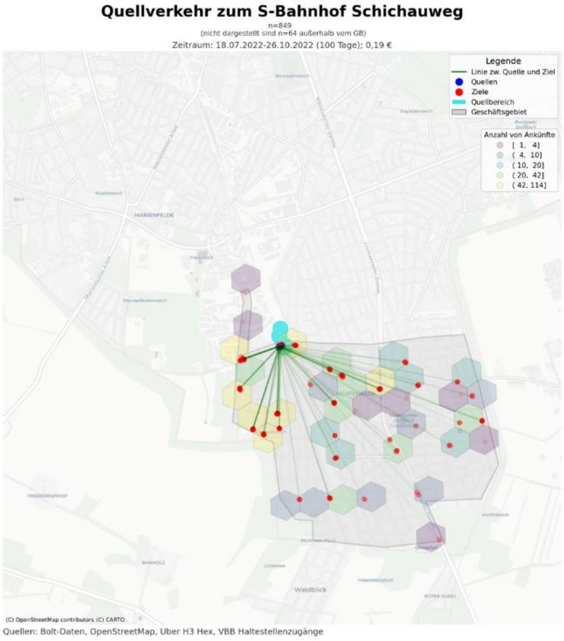
Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge



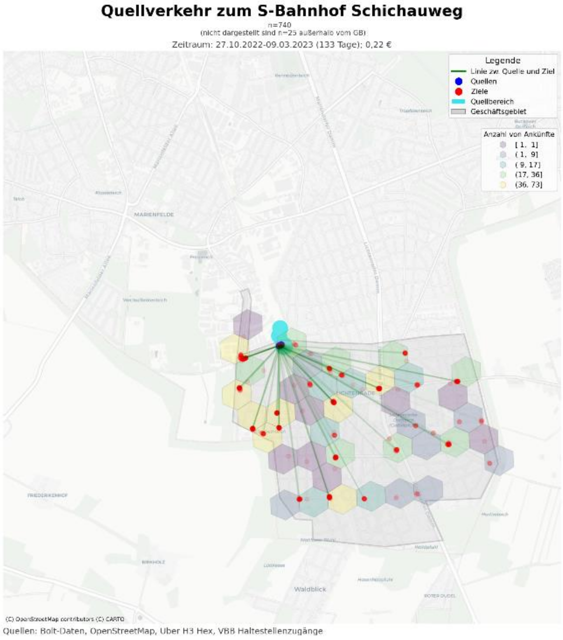
Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

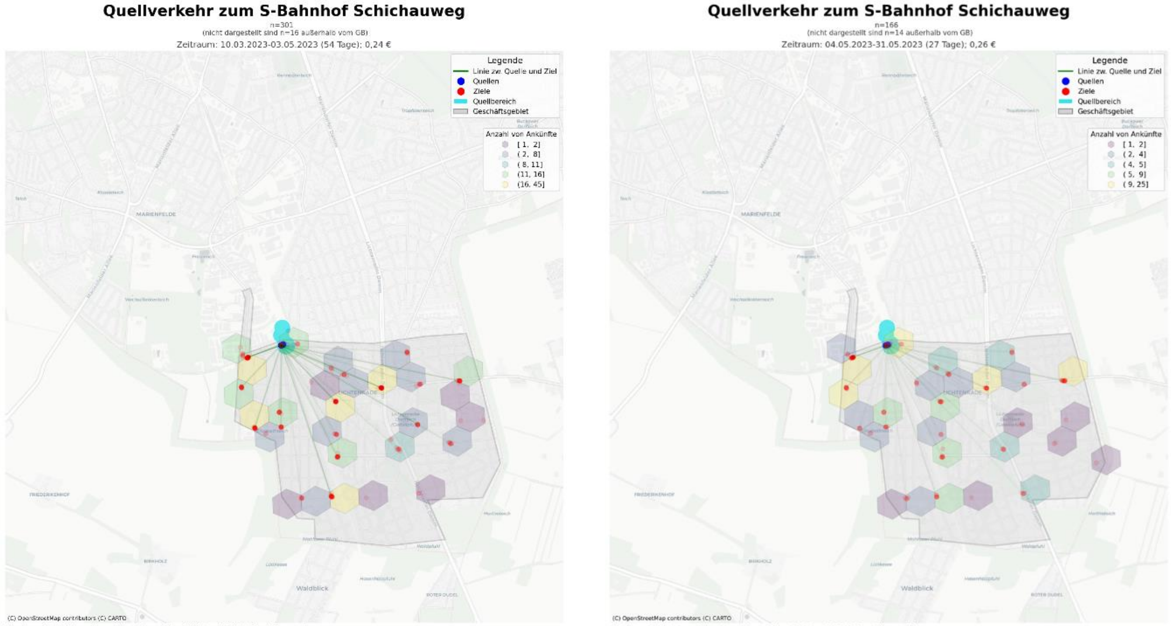
Originating traffic at S-Lichtenrade station



Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge



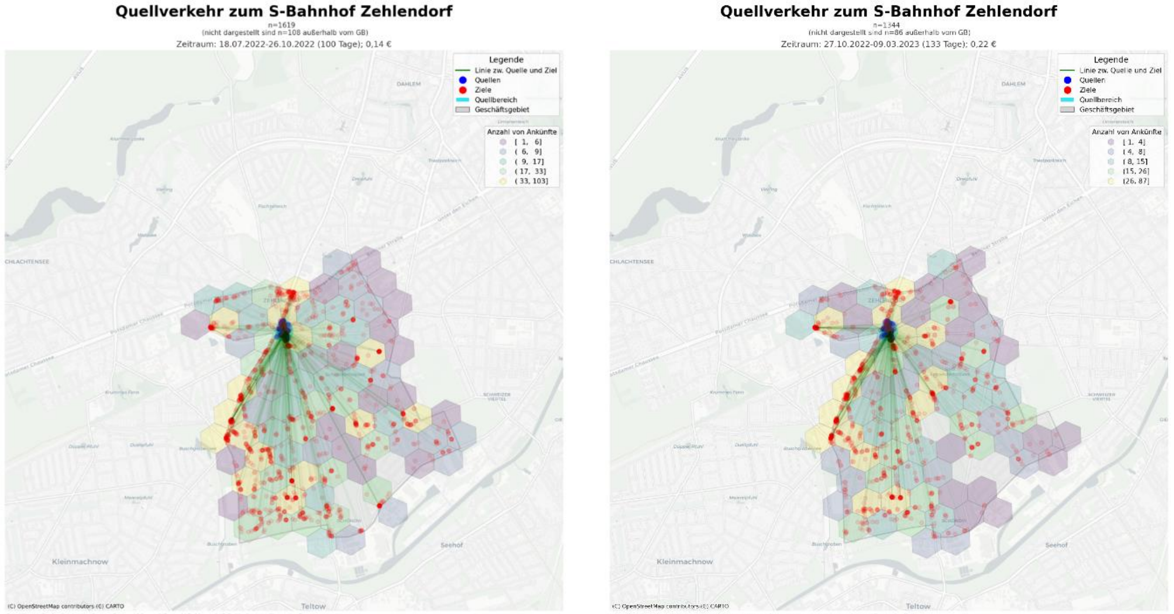
Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge



Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

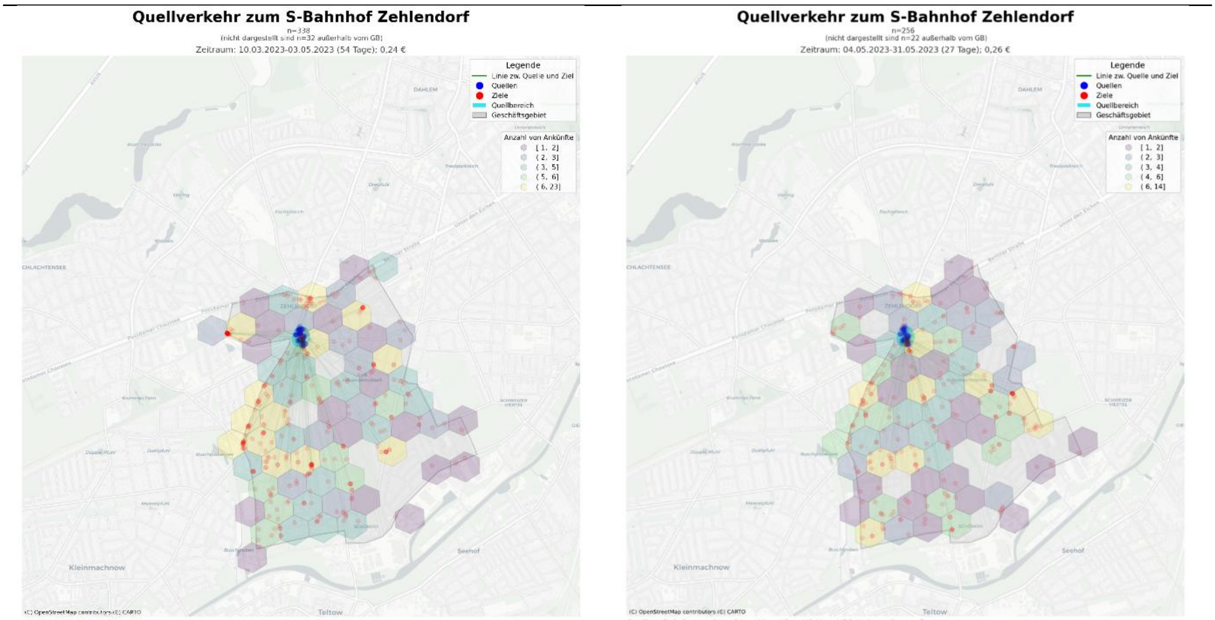
Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Originating traffic at S-Schichauweg station



Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

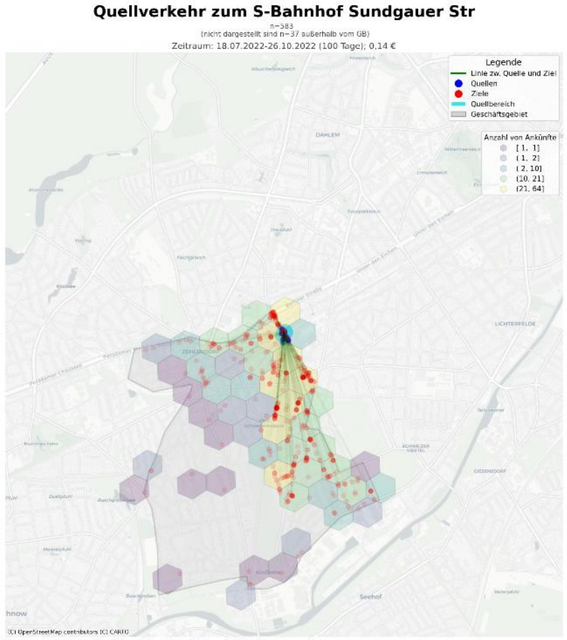
Quellen: Bolt Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge



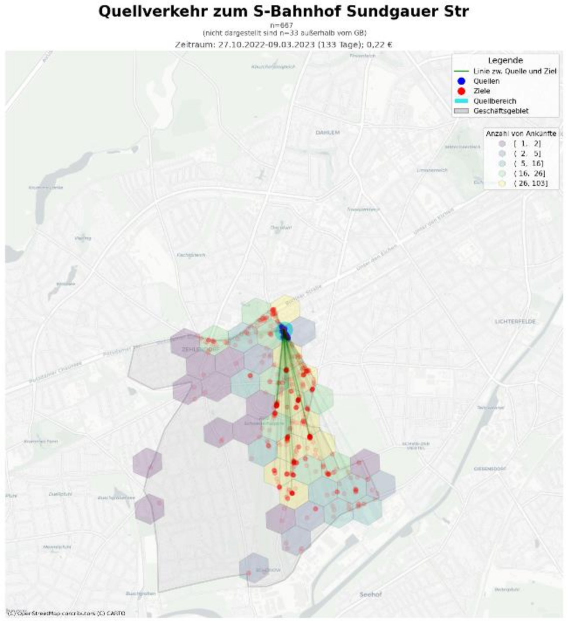
Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

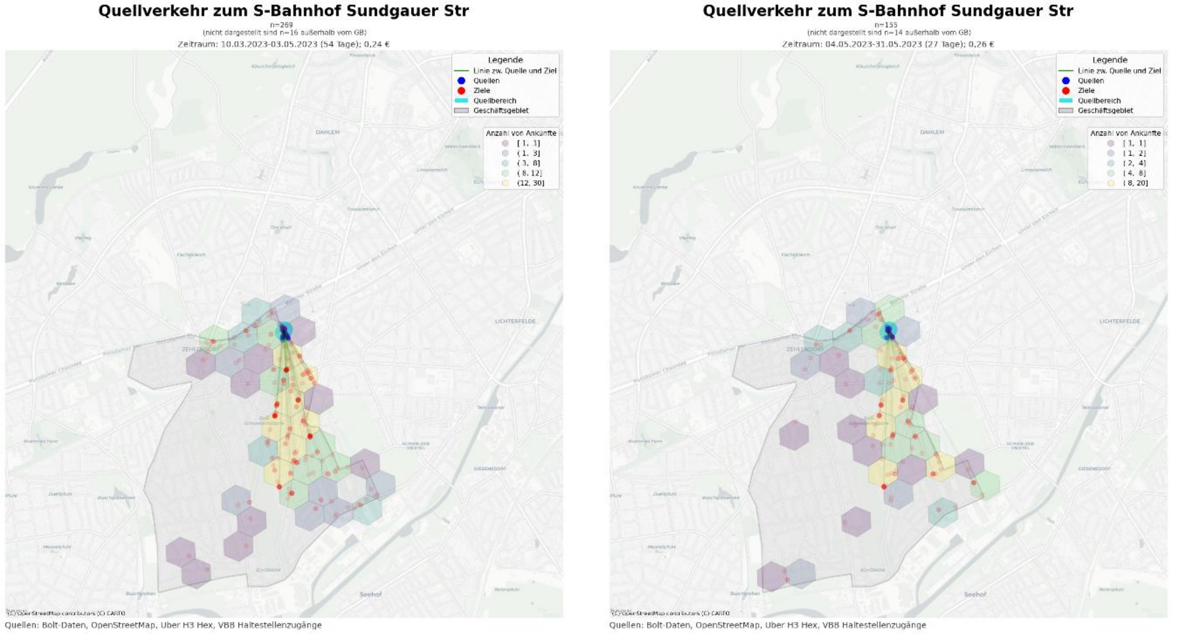
Originating traffic at S-Zehlendorf station



Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge



Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge



Quellverkehr zum S-Bahnhof Sundgauer Str

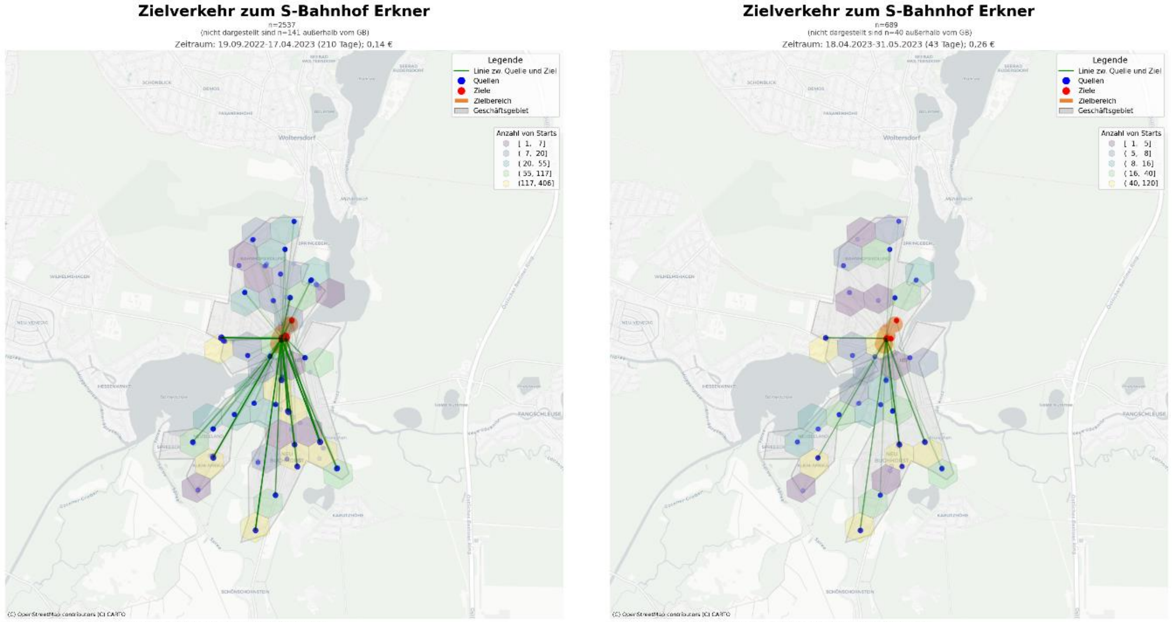
Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Quellverkehr zum S-Bahnhof Sundgauer Str

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Originating traffic S-Sundgauer Straße station

## Target traffic at the S-Bahn train stations in the real-world labs

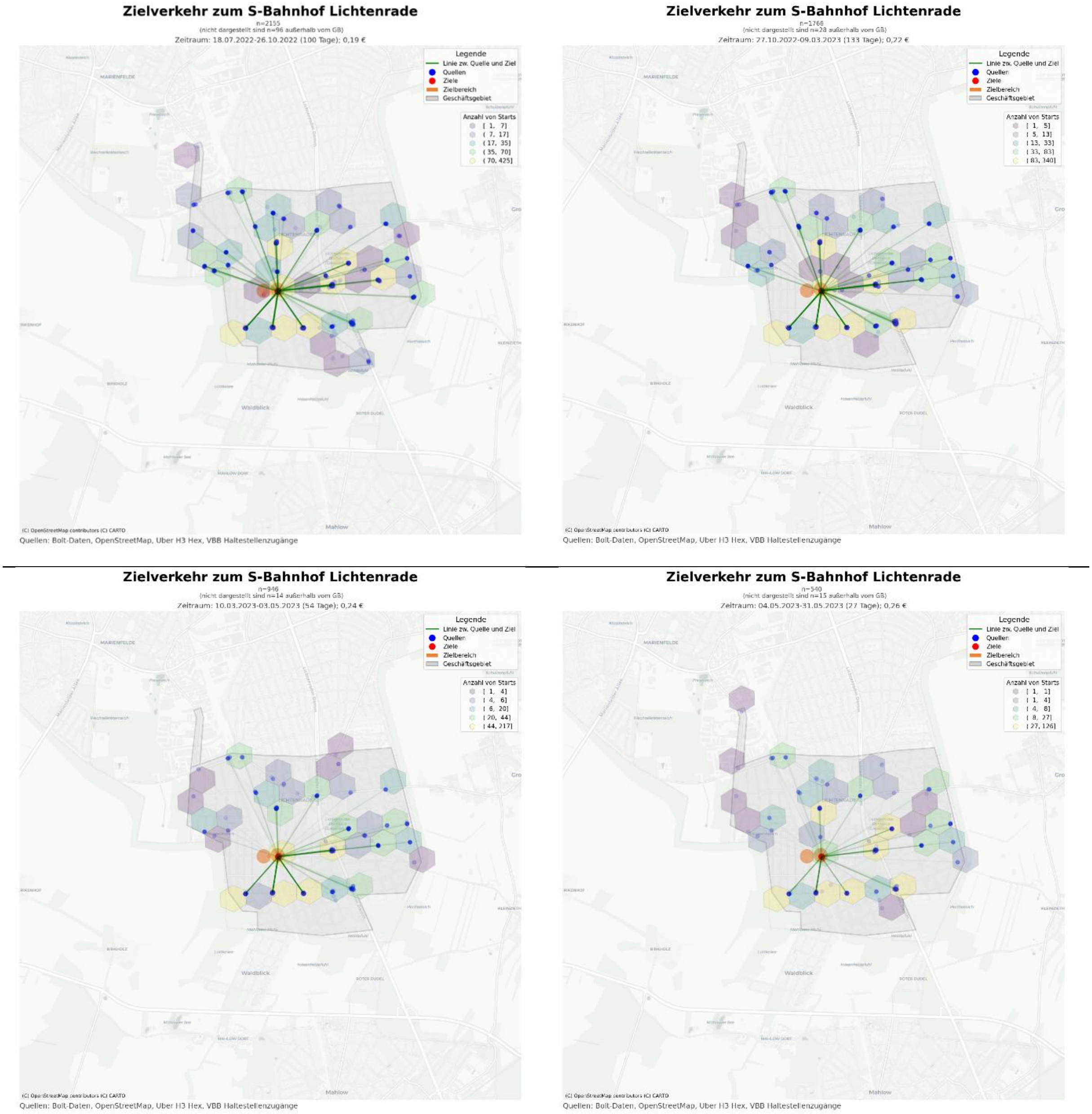

Zielverkehr zum S-Bahnhof Erkner
n=2537
(nicht dargestellt sind n=141 außerhalb vom GB)
Zeitraum: 19.09.2022-17.04.2023 (210 Tage); 0,14 €

Zielverkehr zum S-Bahnhof Erkner
n=689
(nicht dargestellt sind n=40 außerhalb vom GB)
Zeitraum: 18.04.2023-31.05.2023 (43 Tage); 0,26 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Target traffic at S-Erkner station



**Zielverkehr zum S-Bahnhof Lichtenrade**
n=2155
(nicht dargestellt sind n=96 außerhalb vom GB)
Zeitraum: 18.07.2022-26.10.2022 (100 Tage); 0,19 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

**Zielverkehr zum S-Bahnhof Lichtenrade**
n=1766
(nicht dargestellt sind n=28 außerhalb vom GB)
Zeitraum: 27.10.2022-09.03.2023 (133 Tage); 0,22 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

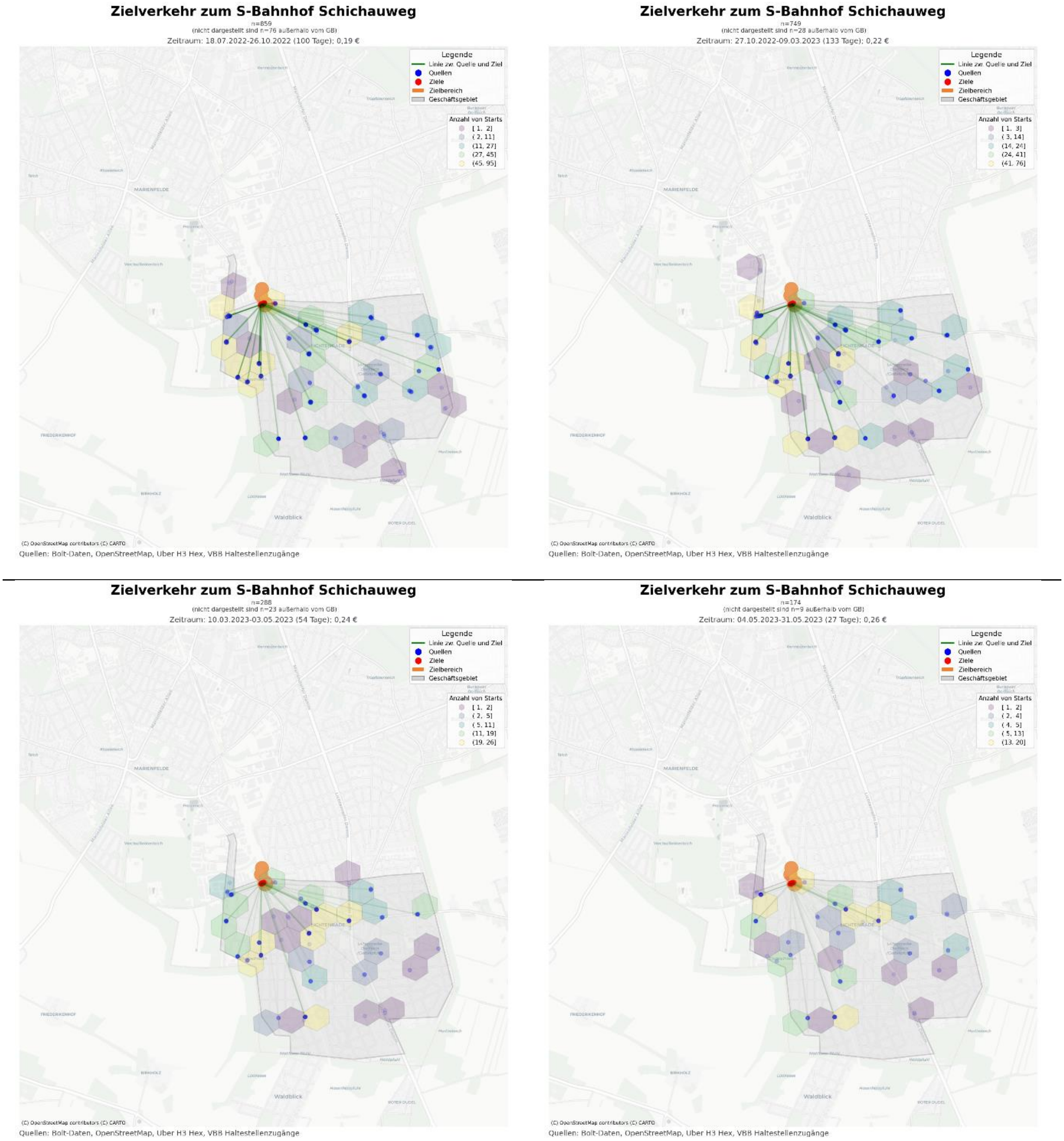
**Zielverkehr zum S-Bahnhof Lichtenrade**
n=946
(nicht dargestellt sind n=14 außerhalb vom GB)
Zeitraum: 10.03.2023-03.05.2023 (54 Tage); 0,24 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

**Zielverkehr zum S-Bahnhof Lichtenrade**
n=540
(nicht dargestellt sind n=15 außerhalb vom GB)
Zeitraum: 04.05.2023-31.05.2023 (27 Tage); 0,26 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Target traffic at S-Lichtenrade station



Zielverkehr zum S-Bahnhof Schichauweg
n=859
(nicht dargestellt sind n=76 außerhalb vom GB)
Zeitraum: 18.07.2022-26.10.2022 (100 Tage); 0,19 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Zielverkehr zum S-Bahnhof Schichauweg
n=749
(nicht dargestellt sind n=28 außerhalb vom GB)
Zeitraum: 27.10.2022-09.03.2023 (133 Tage); 0,22 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

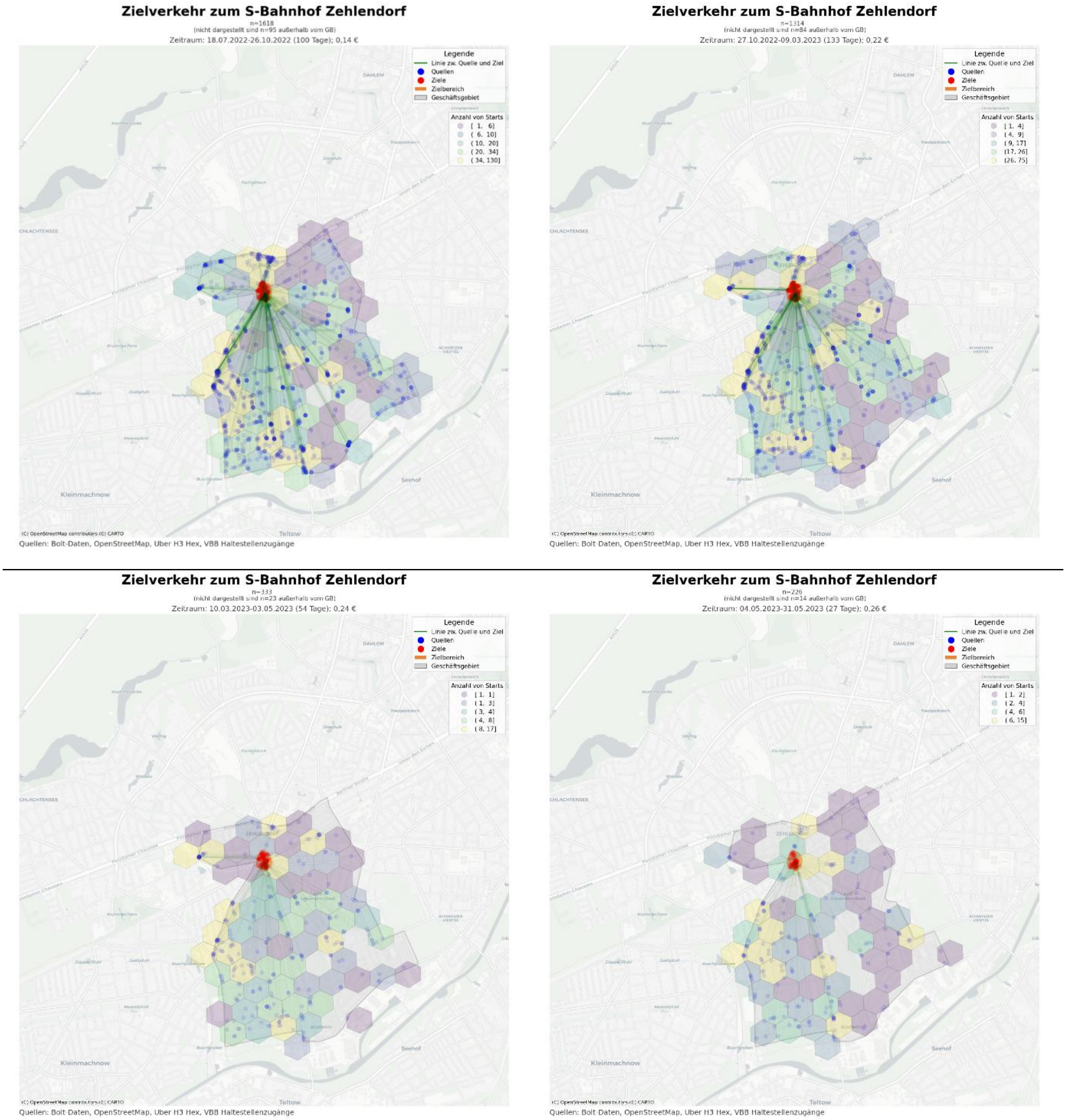
Zielverkehr zum S-Bahnhof Schichauweg
n=288
(nicht dargestellt sind n=23 außerhalb vom GB)
Zeitraum: 10.03.2023-03.05.2023 (54 Tage); 0,24 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Zielverkehr zum S-Bahnhof Schichauweg
n=174
(nicht dargestellt sind n=9 außerhalb vom GB)
Zeitraum: 04.05.2023-31.05.2023 (27 Tage); 0,26 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Target traffic at S-Schichauweg station



Zielverkehr zum S-Bahnhof Zehlendorf
n=1618
(nicht dargestellt sind n=95 außerhalb vom GB)
Zeitraum: 18.07.2022-26.10.2022 (100 Tage); 0,14 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Zielverkehr zum S-Bahnhof Zehlendorf
n=1314
(nicht dargestellt sind n=84 außerhalb vom GB)
Zeitraum: 27.10.2022-09.03.2023 (133 Tage); 0,22 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

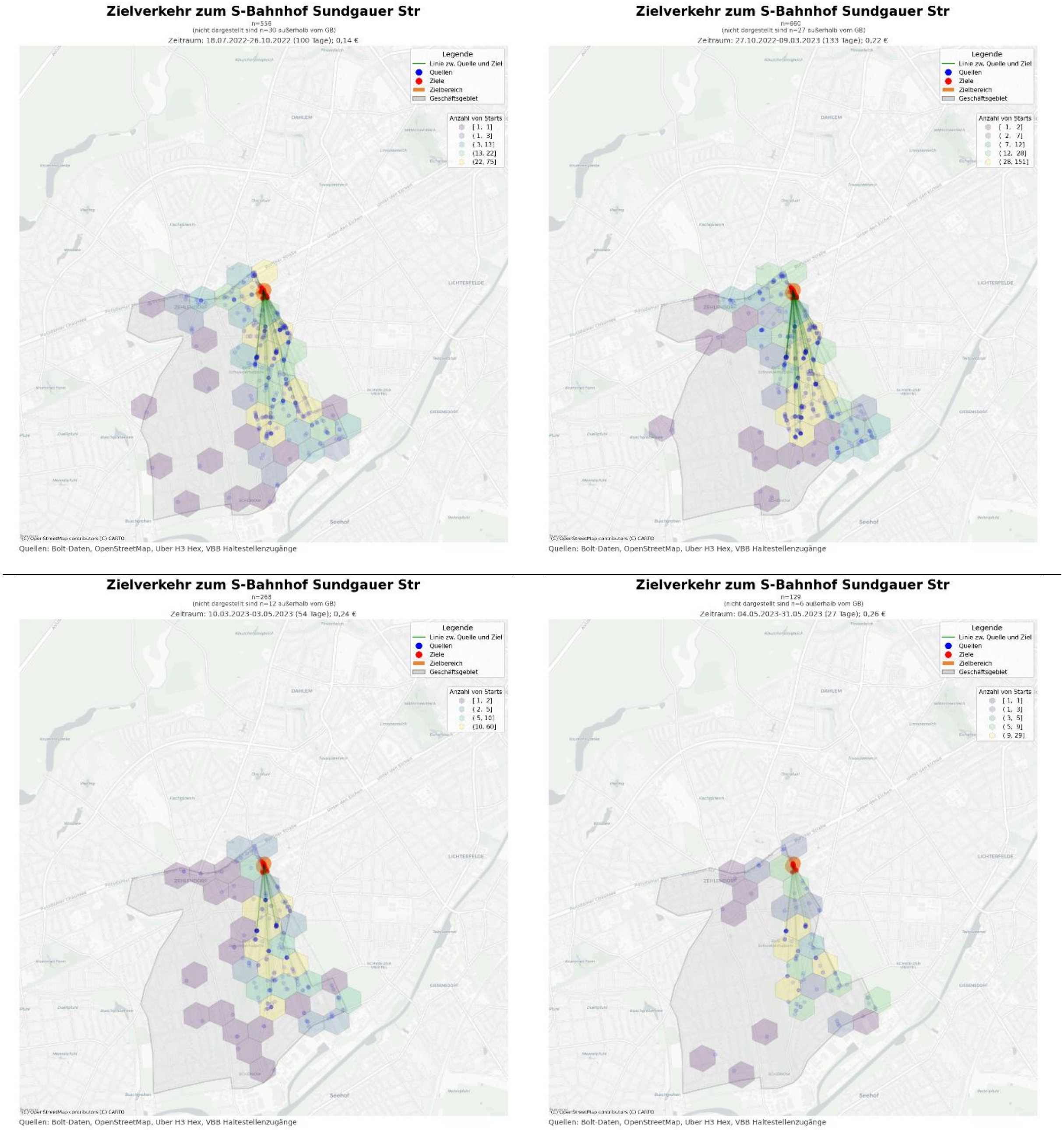
Zielverkehr zum S-Bahnhof Zehlendorf
n=333
(nicht dargestellt sind n=23 außerhalb vom GB)
Zeitraum: 10.03.2023-03.05.2023 (54 Tage); 0,24 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Zielverkehr zum S-Bahnhof Zehlendorf
n=226
(nicht dargestellt sind n=14 außerhalb vom GB)
Zeitraum: 04.05.2023-31.05.2023 (27 Tage); 0,26 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Target traffic at S-Zehlendorf station



Zielverkehr zum S-Bahnhof Sundgauer Str
n=556
(nicht dargestellt sind n=30 außerhalb vom GB)
Zeitraum: 18.07.2022-26.10.2022 (100 Tage); 0,14 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Zielverkehr zum S-Bahnhof Sundgauer Str
n=660
(nicht dargestellt sind n=27 außerhalb vom GB)
Zeitraum: 27.10.2022-09.03.2023 (133 Tage); 0,22 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Zielverkehr zum S-Bahnhof Sundgauer Str
n=268
(nicht dargestellt sind n=12 außerhalb vom GB)
Zeitraum: 10.03.2023-03.05.2023 (54 Tage); 0,24 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Zielverkehr zum S-Bahnhof Sundgauer Str
n=129
(nicht dargestellt sind n=6 außerhalb vom GB)
Zeitraum: 04.05.2023-31.05.2023 (27 Tage); 0,26 €

Quellen: Bolt-Daten, OpenStreetMap, Uber H3 Hex, VBB Haltestellenzugänge

Target traffic at S-Sundgauer Straße station

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## List of Images

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## Publications in the course of the project work

Schuete, N. & Buerklen, A. (in print) A cross-case comparison of the use of sharing mobility services in Germany. World Conference on Transport Research - WCTR 2023 Montreal 17-21 July 2023. Transportation Research Procedia 00 (2023) 000–000).